# Viking Telecommunication Effects of GEOS Satellite Interference Based on Testing at the Madrid Deep Space Station

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*In support of the ongoing NASA–European Space Agency (ESA) effort to understand and control possible interference between missions, testing was conducted at the Madrid Deep Space Station from July 1975 to February 1976 to characterize the effect on Viking 1975 telecommunication link performance of Geodetic Earth-Orbiting Satellite (GEOS) downlink signals. The prime use of the data was to develop a capability to predict GEOS interference effects for evaluation of Viking 1975 mission impacts and possible temporary GEOS shutdown. Also, the data would serve as a basis for assessment of the GEOS impact on missions other than Viking as well as for more general interference applications. Performances of the reference receiver, telemetry, and planetary ranging were measured in the presence of various types of GEOS-related interference, including an unmodulated GEOS carrier and simulation of the actual spectrum by an ESA-supplied GEOS suitcase model. This article describes the testing performed at the Madrid Deep Space Station and the potential GEOS interference impacts on the Viking Extended Mission.*

## I. Introduction

The European Space Agency (ESA) Geodetic Earth-Orbiting Satellite (GEOS) geosynchronous satellite presents a significant interference potential for all NASA deep space missions since the downlink carrier frequency is in the deep space allocation band at channel 26.2 (2299.5 MHz). The Viking channels are 9 and 20 for the Orbiters and 13 for the Landers. A total GEOS power of −90 dBm is expected on-axis at the 64-meter stations.

The potential GEOS interference impacts of $-90$ dBm on-axis levels are severe since the reference receiver and the telemetry are likely to be knocked out of lock. This will occur for a spacecraft operating at any channel across most of the deep space band when the desired signals are at or near threshold. In particular, the farthest Viking channel 9 would be affected. GEOS spectrum components as much as 90 dB down from the total GEOS power are of interest for $-90$ dBm on-axis levels. Such levels are difficult to measure and control so that their presence must be assumed at the worst-case frequency location. The question is how far off the DSN antenna axis must GEOS be geometrically in order not to cause a problem. The answer for Viking appears to be at least 3 degrees. This should preclude any noticeable degradation for normally expected Viking levels with worst-case frequency alignment of the interfering spectrum.

While the immediacy of the interference problem has been alleviated somewhat by the GEOS launch postponement from August 1976 to April 1977, its potential impact remains for the Viking Extended Mission, Mariner Jupiter-Saturn 1977 and Pioneer Venus 1978. The DSN Network Control Center will be responsible for the operating interface with ESA relative to interference and will work in accordance with established detailed procedures and priorities. The tests described herein are in support of the ongoing NASA–ESA effort to understand and control interference.

## II. Test Objective

The test objective was to characterize the effect of GEOS interference on Viking Orbiter (VO) and Viking Lander (VL) telecommunication link performance. Use of the test results was planned for:

(1) Evaluating Viking mission impact and possible GEOS shutdown.

(2) Evaluating GEOS impacts on missions other than Viking.

(3) Miscellaneous potential interference applications.

## III. Test Approach

An investigative approach was emphasized such that subsets of tests could be performed as required to understand unpredicted degradation mechanisms and to characterize their effects.

(1) The saturation characteristics of each system element and its performance impact were investigated as a function of signal level and frequency offset.

(2) A significant unpredicted mechanism was identified during strong signal testing and was independently investigated. Sidebands were found to be generated within the station telemetry and ranging channels due to multiplication of an interfering component by the channel demodulation reference square wave.

## IV. Tests Performed

The performance of each downlink function for selected VO and VL modes was measured in the presence of various types of GEOS-related interference at strong and weak signals and with various frequency offset conditions. Table 1 summarizes the tests performed.

### A. Types of Interference

Four types of interference were used:

(1) Unmodulated GEOS carrier (CW).

(2) Worst-case line spectrum at GEOS frequencies.

(3) Spectrum simulating typical GEOS condition.

(4) Spectrum of GEOS suitcase model supplied by ESA.

Most of the tests were performed with CW since this type signal is most effective for investigative results. In particular, the total power effects could be separated from other interference, and telemetry and ranging channel multiplication harmonics could be more easily isolated and their effects evaluated. Also CW data could be more readily extrapolated for GEOS effects on missions other than Viking as well as for more general interference applications. The worst-case line spectrum testing bounded the potential effects on Viking, since line spectrum effects are expected to be the most severe. Use of a simulated GEOS spectrum provided a preliminary look at probable GEOS effects and also provided a look at the effects of a more nearly continuous type of spectrum. Use of the GEOS suitcase model verified that the actual GEOS spectrum will typically produce results predicted based on analysis and tests.

### B. Parameters Varied

Strong interfering signals were used primarily to determine saturation effects and the maximum GEOS level was −85 dBm. Interfering GEOS signals as low as −140 dBm were tested with Viking signals ranging from the maximum predicted orbital design values to specified thresholds.

All of the Viking frequency channels (9, 13, 16, and 20) were tested with at least CW, and the worst-case channel 20 was used most extensively. The nominal GEOS frequency was set for 2299.5 MHz. The GEOS frequency was adjusted to place multiplication harmonics at various offsets from the Viking channel frequency.

Viking telemetry modes tested included uncoded low rate at 33-1/3 b/s (for low rate only and with high rate on) and coded high rate at 500 b/s, 1 kb/s and 8 kb/s.

### C. Performance Parameters Measured

The carrier, telemetry and ranging performance were each measured.

(1) Carrier performance included suppression in the receiver, phase jitter and the maximum interference level at which the receiver could acquire a Viking signal of a given level.

(2) Telemetry performance included saturation levels in the telemetry string, drop-lock conditions, and $ST_B/N_0$ degradation. Bit and word error rates were also measured. However, error rate results agreed well with $ST_B/N_0$ and only $ST_B/N_0$ was reported for brevity.

(3) Ranging performance consisted of $P_R/N_0$ degradation. DRVID standard deviation was also measured. However, DRVID results agreed well with $P_R/N_0$ and only $P_R/N_0$ was reported for brevity.

In addition to measuring performance of various telecom links, the simulated GEOS spectrums were examined to assure they were as predicted and to search for significant spurious signals.

## V. Prediction Models

Models were developed in some cases to compare with observed test results and can be used to predict effects in flight.

### A. Receiver Carrier Suppression

A model was generated for Viking carrier suppression in the RF receiver assuming a soft limiter for each saturating module:

$$\alpha = \frac{1 + P_V/P_L + P_N/P_L}{1 + P_V/P_L + P_N/P_L + P_I/P_L}$$

where

$\alpha$ = suppression factor

$P_V$ = Viking power

$P_N$ = noise power

$P_I$ = GEOS interfering power

$P_L$ = limit level power

For $P_L$ and $P_I$ much greater than $P_V$ or $P_N$, this simplifies to

$$\alpha \approx \frac{1}{1 + P_I/P_L}$$

The S-band mixer and 50 MHz intermediate frequency (IF) amplifier and mixer are the most significant modules, since saturation in other modules occurs at substantially higher levels. The power levels for the S-band mixer are referenced at the maser input and $P_L$ is −79 dBm (based on measured data). For the 50-MHz IF, the closed loop automatic gain control (AGC) increases the gain to compensate for suppression of the Viking signal. This also increases the GEOS "linear" output and consequently the suppression such that a cumulative effect occurs. At equilibrium, the Viking output level is −81 dBm (by loop design), while the "linear" GEOS output has increased by the amount Viking has been suppressed. For the 50-MHz IF suppression factor, powers are referenced to the module output, $P_L$ is −10 dBm (based on measured data) and $P_I$ is the "linear" GEOS output. The total receiver suppression is the sum of the values for the S-band mixer and 50-MHz IF modules. Frequency separation considerations are excluded from the above equations and can be accounted for by reducing the interference level according to bandwidth losses.

### B. Interfering Sidebands Generated Within Receiver

Interfering sidebands are generated within the receiving station telemetry and ranging channels due to multiplication of an incoming interfering component by the channel demodulation reference square wave. In the case of telemetry, this occurs in the Subcarrier Demodulator Assembly (SDA) quad generator, where the reference is a square wave at the subcarrier frequency. In the case of ranging, this occurs in the 10-MHz IF amplifier and phase switch, where the reference is a square wave at the clock frequency of about 516 kHz (for postacquisition tracking). The odd multiplication harmonic nearest the channel 10-MHz center frequency is the closest odd integer to $\Delta f / f_{REF}$ and is nominally at a frequency offset of

$$\Delta f_N = \Delta f - N f_{REF}$$

where

$N$ = number of multiplication harmonic nearest the desired signal center frequency

$\Delta f_N$ = frequency offset of nearest harmonic from the desired signal frequency

$\Delta f$ = nominal frequency separation between interference and the desired signal.

$f_{REF}$ = frequency of channel reference square wave

The level of a given multiplication harmonic produced by an interfering signal line component is determined from

$$P_N = P_I \left( \frac{2}{N\Pi} \right)^2$$

where

$P_N$ = power in the $n$th multiplication harmonic

$P_I$ = power in the interfering signal line component

Frequency separation considerations are excluded from the equation for $P_N$ and can be accounted for by reducing the interference level according to bandwidth losses.

### C. Condition for Telemetry SDA Drop-Lock

The telemetry channel SDA will be knocked out of lock when the interfering sideband is approximately equal in power to the desired telemetry data, with a frequency offset from the desired signal of half the data symbol rate. The level of an interfering signal line component which can produce such a multiplication harmonic is

$$P_I = P_D \left( \frac{N\Pi}{2} \right)^2$$

where

$P_D$ = desired signal telemetry data power

### D. Condition for Interfering Signal Spectral Density = $N_0$

When the interfering signal spectral density is nearly continuous and is approximately equal to the receive noise spectral density in a given channel, degradation of approximately 3 dB will occur. Assuming the interfering signal spectrum to be uniform across a given bandwidth, the level of the interfering signal data power which can produce multiplication harmonic spectral density equal to the receive noise spectral density in the channel of interest is

$$P_{ID} = k T_{sys} B \left( \frac{N\Pi}{2} \right)^2$$

where

$P_{ID}$ = interfering signal data power

$k$ = Boltzmann's constant

$T_{sys}$ = receiving system noise temperature

$B$ = bandwidth in region of interfering spectrum whose multiplication harmonic is near the frequency of the desired signal over which power is uniform.

## VI. Carrier Tracking Test Results

Carrier tracking performance was evaluated based on the measurement of carrier suppression in the receiver and the effects on receiver acquisition and coherent doppler jitter. The higher levels required for acquisition and the increased doppler jitter in the presence of interference are each the result of suppression. While data discussed below were measured using a CW signal, results for other GEOS spectrums were in agreement on a total power basis. That is, since the GEOS spectrum is narrow as compared to the receiver bandpass and the frequency between GEOS and the Viking channels, total GEOS power is the important parameter for receiver saturation effects.

### A. Carrier Suppression

Figure 1 shows the Viking carrier suppression in dB measured by AGC for the worst-case channel 20 as a function of CW interference level at the GEOS frequency. The predicted suppression using the model of paragraph VA is shown for comparison.

### B. Acquisition Levels

Table 2 summarizes the maximum CW interference levels at which the Viking carrier could be acquired with the Viking frequency at a static value equal to the receiver rest frequency for channels 9, 13, 16 and 20.

## C. Doppler Phase Jitter

Figure 2 shows doppler phase jitter as a function of CW interference level for the worst-case channel 20.

# VII. Telemetry Test Results

Levels were measured at which telemetry string saturation occurred, but the saturation effects were found to be secondary to the degradation by multiplication harmonics. Telemetry $ST_B/N_0$ degradation and the level at which drop-lock occurred were measured for various interference conditions resulting from harmonics generated by SDA reference multiplication of the GEOS input. Line spectrum multiplication harmonic effects were found to be the most severe. Multiplication harmonic energy from near-continuous interfering spectrums has a significant effect only as the level approaches that of the inherent receiver noise. Since the line spectrum effects are most severe, the CW case provides an excellent bounding measure of degradation effects and results can be easily extrapolated to other cases. In particular, the results for the GEOS carrier with modulating spectrums are in agreement with the CW case on a carrier power basis. That is, the modulated carrier is the strongest component producing harmonics from multiplication and its effect dominates over modulating components. Further, any case where line interference is involved will differ from the CW only by the level of the interfering line.

## A. Telemetry Saturation

The 10-MHz SDA is the first stage to saturate and does so for a level of interfering GEOS power within the telemetry channel bandwidth of $-95$ dBm, referenced at the traveling-wave maser (TWM) input.

## B. Telemetry Drop-Lock Due to Multiplication Harmonics

Table 3 summarizes the levels of CW interference for drop-lock of Viking telemetry at an $ST_B/N_0$ of 8 dB with the GEOS frequency adjusted for the nearest multiplication harmonic offset at half the telemetry symbol rate from the Viking operating frequency. With the interfering harmonic slightly offset from the Viking operating frequency, interfering levels for drop-lock were about 2 dB weaker than for half the symbol rate. With the harmonic near the edge of the band, drop-lock levels were about 10 dB stronger than for half the symbol rate. It is noted that for interference exactly at the Viking operating frequency, the effect is less severe than with a slight offset. Drop-lock occurs at a level about 6 dB stronger with no offset than with a slight offset. Based on the results of Table 3, the differences in severity of interference effects relative to channel 20 are about 9 dB for channel 16, 17 dB for channel 13 (with orbiter subcarriers), and 26 dB for channel 9.

While the above results are for a CW signal, results for other GEOS spectrums were in agreement on a carrier power basis, since the modulated carrier dominates over the modulating components.

## C. Telemetry $ST_B/N_0$ Degradation by Multiplication Harmonics

Telemetry $ST_B/N_0$ degradation data presented below are limited to:

(1) Multiplication harmonic interference.

(2) Worst-case Viking channel 20.

(3) Interfering spectrum cases of CW and the GEOS suitcase model.

The CW interference is the worst case since lines produce the most severe degradation and the power is confined to a single line. The suitcase model is the expected case and includes both lines (sidebands of the high-rate telemetry subcarrier at 190.5 kHz) and near-continuous portions (modulating data energy).

Figures 3, 4, and 5 show three Viking telemetry modes: cruise at 33-1/3 b/s (uncoded low rate only), coded high rate at 1 kb/s and coded high rate at 8 kb/s, respectively. Each is with an unmodulated GEOS carrier (CW) adjusted in frequency for the nearest multiplication harmonic at various offsets from channel 20. The following observations are made:

(1) While the most severe $ST_B/N_0$ degradation occurs for the CW line at a slight offset from channel 20, an offset of half the Viking symbol rate is only slightly less severe.

(2) Degradation with the CW line exactly on channel 20 is much less severe than a slight offset.

(3) Degradation is least severe for 33-1/3 b/s and coded 1 kb/s with the CW line near the telemetry band edge. The severity is reduced by about 13 dB relative to the worst-case slight offset.

(4) For symbol rates greater than 5000 per second, the bandwidth of 500 kHz is sufficiently wide that an odd multiplication harmonic will always fall within the bandwidth. This is because the odd harmonics

from multiplication with the Viking subcarrier are spaced at 480 kHz, or twice the subcarrier frequency of 240 kHz. This is important since the use of ground frequency tuning can minimize but cannot remove the interference.

(5) When two harmonics fall in the telemetry bandwidth simultaneously, increased degradation over the case of a lesser frequency offset is produced. This is illustrated in Fig. 5 for the 8-kb/s case, where the maximum offset of 240 kHz produced a more severe effect than 200 kHz.

Figure 6 shows the Viking coded high-rate telemetry at 1 kb/s with the GEOS suitcase model spectrum. The GEOS frequency was adjusted to place the multiplication harmonic interference at a frequency offset of half the symbol rate from channel 20. The three cases shown are for the multiplication harmonic interference produced by the modulated GEOS carrier, the first GEOS telemetry subcarrier sideband, and the strongest portion of the GEOS telemetry data spectrum. The following observations are made:

(1) The modulated GEOS carrier produces the most severe degradation due to its line structure and relative strength. It is less severe than the CW case of Fig. 4 by the amount of modulation suppression (approximately 5.5 dB).

(2) The first GEOS telemetry subcarrier sideband produces degradation less severe than the modulated carrier by about the difference in levels of the spectral lines (about 12 dB).

(3) The strongest portion of the GEOS telemetry data spectrum produces only slightly less degradation than the subcarrier sideband. While the maximum data spectrum level is slightly greater than the subcarrier sideband, line structure is less pronounced than is the subcarrier sideband. The effect of a more continuous spectrum is similar to that of increased noise and is less severe than for a well-defined line.

(4) Some portion of the GEOS spectrum will always produce multiplication harmonics in the Viking telemetry bandwidth for any channel, regardless of the relative frequency alignment or the Viking telemetry bandwidth. This is important since the use of ground tuning can only minimize the effect. The minimum effect should occur with on-channel location of the multiplication harmonics from the GEOS data spectrum in the region of 143 kHz from the GEOS carrier (halfway between the subcarrier and the maximum data level). It was verified by measurement using a simulated GEOS spectrum for the coded 1-kb/s case that this portion of the data spectrum was about 5 dB less severe than the strongest portion.

(5) With frequency alignment for multiplication harmonics of the 143-kHz data spectrum region, the 50-kHz telemetry bandwidth for 1 kb/s tends to preclude harmonics from either the subcarrier (at 190.5 kHz) or the strongest portion of the data spectrum (at about 95 kHz). However, for symbol rates greater than 5000 per second the 500-kHz telemetry bandwidth will allow harmonics of the carrier, subcarrier, and data spectrum simultaneously. While no data were measured for the 500-kHz bandwidth using the GEOS data spectrum, degradation can be bounded by the interference levels for the CW case and as much as 18 dB stronger. For example, with coded 8 kb/s on channel 20, the modulated GEOS spectrum will produce drop-lock for a total GEOS power of no less than about $-117$ dBm (CW case) and no greater than about $-99$ dBm. The 18-dB difference assumes that the strongest level required is that of a modulated carrier near the band edge. The measured data in Fig. 5 show that the ninth CW harmonic at a 200-kHz offset is about 13 dB less severe than for the worst-case slight offset. To this, 5-dB modulation suppression must be added. The 1-kb/s data of Fig. 6 also tend to confirm this, since the strongest level for the least of the major interfering spectrum components is about 12 dB less than for the modulated carrier.

## VIII. Ranging Test Results

For interfering signals outside the narrow channel bandwidth, ranging signal suppression due to overall receiver saturation is the dominant effect and is the same as for the carrier. For signals within the ranging channel bandwidth, additional degradation occurs due to ranging module saturation and the appearance of interference as noise at the ranging detector. Investigative tests show the low-pass (LP) dc amplifier to be the first ranging channel saturation component. The two most significant bandwidths are the $\pm 225$ Hz of the crystal filter (about 10 MHz) and the $<1$ Hz of the LP dc amplifier. Figure 7 shows the Viking channel 20 ranging $P_R/N_0$ degradation as a function of CW interference level for various frequency offsets from the Viking operating value. The data were obtained for a downlink carrier of $-152$ dBm (minimum level at maximum range) and a $P_R/N_0$ of $+12$ dB (in the absence of interference). The interfering sideband was the nearest harmonic (5th) produced by multiplication of the interfering carrier by a 516-kHz reference square wave. This is not an expected Viking condition since the potential GEOS/Viking frequency separation will not allow a GEOS carrier multiplication harmonic so near any Viking channel. The nominal separation between any Viking channel and the GEOS frequency places the nearest odd ranging clock harmonic at an offset from the Viking channel greater than the combined uncertainties of the Viking and GEOS operating frequencies and the DSN receiver offset from the channel 20 center frequency to account for doppler. Since the DSN transmitter frequency is offset to account for the Earth–Mars uplink doppler, the DSN receiver will be offset only by the amount of the downlink Earth–Mars doppler. The nominal offsets of the nearest odd ranging clock harmonics are 300 kHz for channels 9 and 20 and 227 kHz for channel 13. The downlink Earth–Mars doppler will not exceed 125 kHz, and the combined frequency uncertainties will not exceed 90 kHz. While interference is highly unlikely for Viking in the postacquisition mode (516-kHz clock only), it is the most meaningful mode to test and is useful for extrapolation to other cases. Observations of data with the 516-kHz clock 5th harmonic at various frequency offsets from the Viking channel 20 are made as follows:

(1) Figure 7 shows that the worst-case degradation is for the interfering multiplication harmonic aligned with the Viking channel 20. Here the effect as increased noise in the detection bandwidth dominates.

(2) For increasing frequency offset (1.2 to 33.6 Hz in Fig. 7), the LP dc amplifier bandpass characteristic will increasingly attenuate the interfering harmonic and reduce its effect as increased noise until the noise and suppression effects are constant relative to each other.

(3) After frequency offsets for which the relative noise and suppression effects are essentially constant (33.6 Hz in Fig. 7), added offset will merely attenuate both effects equally by the amount of the crystal filter insertion loss. The attenuation for an offset slightly beyond the ±225-Hz bandwidth (500 Hz in Fig. 7) becomes a nearly constant 20 dB.

(4) For offsets significantly beyond the ±225-Hz crystal filter bandwidth, levels of interference required to produce LP dc amplifier saturation and increased detector noise will first cause receiver saturation. That is, outside the ranging channel bandwidth, receiver saturation will be the predominant interference effect.

## IX. GEOS Spectrum Examination

The spectrum of the GEOS suitcase model was examined to assure that it was as predicted and to search for any spurious signals. The regions within channels 9, 13 and 20 were obtained carefully for the unmodulated carrier as well as the modulated case with a total GEOS power of $-85$ dBm. The worst-case line spectrum was examined as well, but only in the region of channel 20. In all cases the spectrum was essentially as predicted and no spurious signals were found. However, signals were found which were not GEOS output components but were intermodulation products of well-defined spectral lines generated within the saturated receiver 50-MHz IF amplifier and mixer. This was confirmed when the signals disappeared with the addition of a ±1-MHz filter at the 50-MHz IF module input. These signals had levels as strong as $-155$ dBm in channel 20. Acquisition of these signals required a special operating procedure due to the saturation condition. By using manual gain control (MGC) at an appropriate level some suppression could be avoided.

## X. Potential Mission Impacts

The expected GEOS level along a 64-m antenna boresight is $-90$ dBm. At this level the protection normally afforded by frequency separation is significantly reduced. This is because satellite signals far removed from the satellite carrier are of concern even if they are as much as 90 dB weaker than the carrier. Such signals cannot be effectively controlled or even accurately measured and must be assumed to occur. More importantly, as the tests reported herein show, a satellite carrier near the deep space band can cause interference even at relatively weak levels due to generation of harmonics from multiplication by data channel demodulation square wave references.

### A. Viking Extended Mission

A summary of the planned GEOS orbit geometry for the April 1977 launch has been supplied to NASA by ESA. These data are presently under evaluation to determine the times of potential GEOS interference to the Viking Extended Mission, if any. Table 4 is a summary of the worst-case potential effects for each Viking telecommunication link should GEOS cross the main beam of a DSN antenna which is tracking Viking.

It can be seen that the worst-case frequency alignment will knock the high-rate telemetry links out of lock for any Viking channel with the 64-m on-axis GEOS level of $-90$ dBm. Further, regardless of frequency alignment, high-rate drop-lock on channel 20 will occur for a total GEOS power level of $-99$ dBm or lower. Hence, GEOS shutdown appears to be necessary when GEOS is located near the 64-m boresight look direction for Viking. An angle of 3 deg off boresight should produce a total GEOS level of about $-140$ dBm (for $P_c/P_T = -0.5$ dB), which would place the ninth GEOS carrier multiplication harmonic about 22 dB below the Viking data power on channel 20. Measured data indicate that this relative level of interference, even for the worst-case frequency alignment, would produce negligible telemetry $ST_B/N_0$ degradation ($<0.1$ dB). This is in agreement with an analysis by M. A. Koerner (Ref. 1). It should be noted that potential degradation to the ranging channel during acquisitions remains even for the $-140$ dBm GEOS level. However, for the expected Viking $P_R/N_0$ of about 20 dB such degradation depends on a frequency alignment to within 5 or 10 Hz. Such a condition is highly unlikely.

### B. Other Missions

As shown by Viking testing, any channel in the deep space band can be degraded by a satellite downlink near the band having sufficient power. Hence, all NASA deep space missions are potentially susceptible to impacts from GEOS as well as other satellites, present or future.

## Reference

1. Koerner, M. A., *Effect of Interference on a Binary Communication Channel Using Known Signals*, Technical Report 32-1281, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 1, 1968.

**Table 1. Summary of tests conducted to determine Viking susceptibility to GEOS interference**

| Measured performance | | GEOS interference | | | | | | | Viking signals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Spectrum | | | | Interfering component | Offset[a] of interference from Viking frequency | Level, dBm | Channel | Data rate, b/s | Level |
| Function | Parameter | CW | Line | Simulated | Suitcase | | | | | | |
| Carrier | Signal suppression | X | X | X | X | Total power | GEOS @ Ch 26.2 | −85 to −105 | 20,16, 13 and 9 | N/A | −140 to −165 dBm |
| | Acquisition while saturated | X | | X | | Same | Same | Meas | Same | N/A | Same |
| | Jitter | X | X | | | Same | Same | Same | 20 | N/A | −155 to −165 dBm |
| | False lock | | X | | X | Intermods within saturated receiver | Random | −85 | 20,13 and 9 | N/A | N/A |
| Telemetry | Level at which saturation occurred | X | | | | Power in telemetry BW | GEOS @ Ch 26.2 | −95 | 20 | 8k | −145 dBm |
| | Drop-lock and $ST_B/N_0$ degradation | X | | | | Harmonic[b] of CW | 0 to edge of telemetry channel BW | −105 to −135 | 20<br>13<br>9 and 16 | 33-1/3, 1k and 8k<br>500 and 8k<br>8k | $ST_B/N_0$ = 5 and 8 dB |
| | | | X | X | X | Harmonic[b] of modulated GEOS carrier | Half Viking data symbol rate | Same | 20 | 33-1/3 and 1k | $ST_B/N_0$ = 8 dB |
| | | | X | X | X | Harmonic[b] of strongest line | Same | Same | Same | Same | Same |
| | | | | X | X | Harmonic[b] of continuous spectrum between carrier and first line | Same | Same | Same | Same | Same |
| Ranging | $P_R/N_0$ degradation | X | | | | Harmonic[c] of CW | 0 to 500 Hz[d] | −95 to −165 | 20 | $T_{INT}$ = 1 min | $P_R/N_0$ = 12 dB |

[a]GEOS adjusted where required from its nominal value of 2299.5 MHz.

[b]Harmonics are those generated due to multiplication of given signal by the telemetry subcarrier demodulation reference.

[c]Harmonics are those generated due to multiplication of CW by the ranging clock demodulation reference.

[d]Low-pass (LP) dc amplifier BW < 1 Hz and crystal filter BW = ±225 Hz in 10-MHz stage.

**Table 2. Maximum GEOS signal level for Viking receiver acquisition (dBm)**

| Viking channel | Viking signal level | | | | | |
|---|---|---|---|---|---|---|
| | −140 | −145 | −150 | −155 | −160 | −165 |
| 20 | −85[a] | −85[a] | −89 | −91 | −97 | −102 |
| 16 | −85[a] | −85[a] | −87 | −93 | −97 | −103 |
| 13 | −85[a] | −85[a] | −85[a] | −89 | −95 | −101 |
| 9 | −85[a] | −85[a] | −85[a] | −85[a] | −85[a] | − 91 |

[a]No stronger signal level was checked.

**Table 3. Predicted and measured CW power for Viking telemetry drop-lock at an $ST_B/N_0$ = 8 dB with the interfering harmonic offset at half the data symbol rate**

| Viking signal | | | | CW interference | | |
|---|---|---|---|---|---|---|
| RF channel | Telemetry | | | Multiplication harmonic number | Total power, dBm | |
| | Mode | b/s | Coding | | Predicted | Measured |
| 20 | High rate | 8k | Block | 9 | −114.5 | −115 |
| | | 1k | Block | 9 | −123.5 | −124 |
| | | 33-1/3[a] | None | 95 | −118.0 | −115 |
| | Cruise | 33-1/3 | None | 95 | −118.0 | −118 |
| 16 | High rate | 8k | Block | 15 | −103.5 | −106 |
| 13 | High rate | 8k[b] | Block | 21 | −102.0 | − 98 |
| | | 500 | Block | 67 | −104.0 | −101 |
| 9 | High rate | 8k | Block | 27 | − 90.3 | − 89 |

[a]Low rate channel on 24-kHz subcarrier in the high-rate mode with coded 1 kbps simultaneously on a 240-kHz subcarrier.

[b]This case is for orbiter telemetry data rate and subcarrier to compare relative channel separation effects. The lander on channel 13 will in practice transmit a maximum of 500 b/s on a 72-kHz subcarrier.

Table 4. Summary of worst-case potential Viking interference effects due to GEOS based on test data

| Function | Parameter | Interference condition[a] | Mode | Viking degradation[b] Channel 20 | Channel 13 | Channel 9 |
|---|---|---|---|---|---|---|
| Carrier | Signal suppression | Saturation | All | −0.7 dB | −0.2 dB | −0.1 dB |
| | Interference level for acquisition | Saturation | All | None[c] | None[c] | None[c] |
| | Increased jitter | Saturation | All | <1 deg | None | None |
| Telemetry | Total interference power for drop-lock[d] | GEOS carrier multiplication harmonic at slight offset from Viking frequency[e] | 33-1/3 (LRT only) | −103 | −92 | −78 |
| | | | 33-1/3 (HRT) | −117 | −98 | −91 |
| | | | 500 | N/A | −103 | N/A |
| | | | 8k | −117 | N/A | −91 |

[a]GEOS carrier modulated by low speed data only with $P_c/P_T = -0.5$ dB; $P_c/P_T = -5.5$ dB when high speed data on. Carrier frequency near 2299.5 MHz and maximum total power = −90 dBm.

[b]With expected total Viking power of −140 dBm for VO and −147 dBm for VL, each at maximum range.

[c]No degradation since the carrier could be acquired even under the worst-case saturating level of −90 dBm.

[d]1 dB of $ST_B/N_0$ degradation occurs for interference levels about 5 dB weaker than for drop-lock.

[e]Drop-lock occurs at stronger signal by about 2 dB for a frequency offset of half the data symbol rate and by about 12 dB at edge of telemetry BW. Drop-lock occurs for stronger signal by about 6 dB for interference exactly at the Viking frequency.

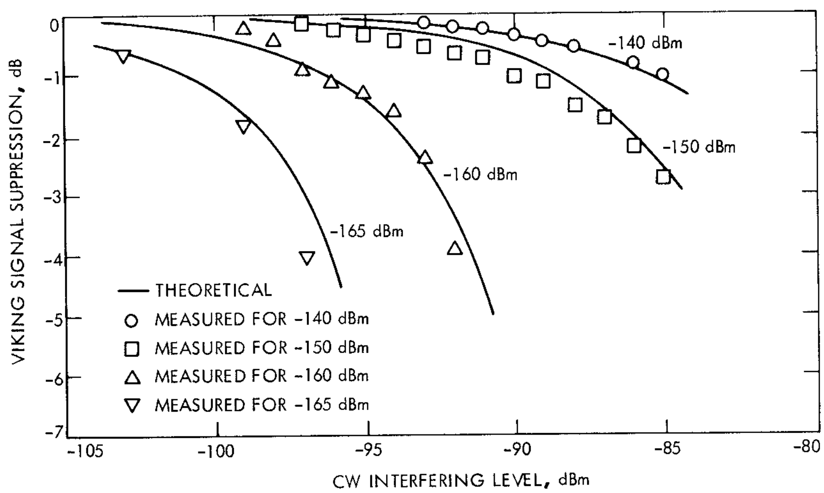


**Fig. 1. Theoretical and measured reference receiver signal suppression on channel 20 vs CW interfering level for various Viking carrier levels**

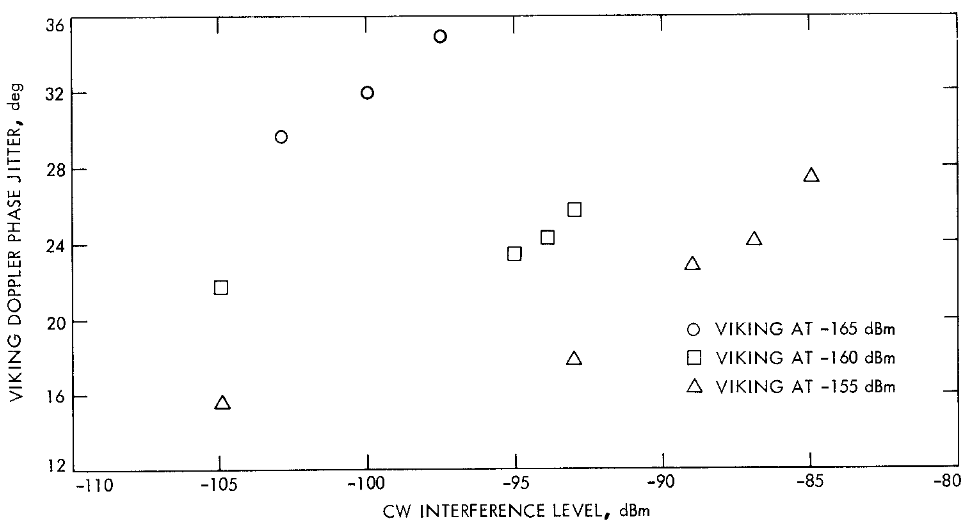


**Fig. 2. Measured doppler phase jitter on channel 20 vs GEOS level for various Viking carrier levels**

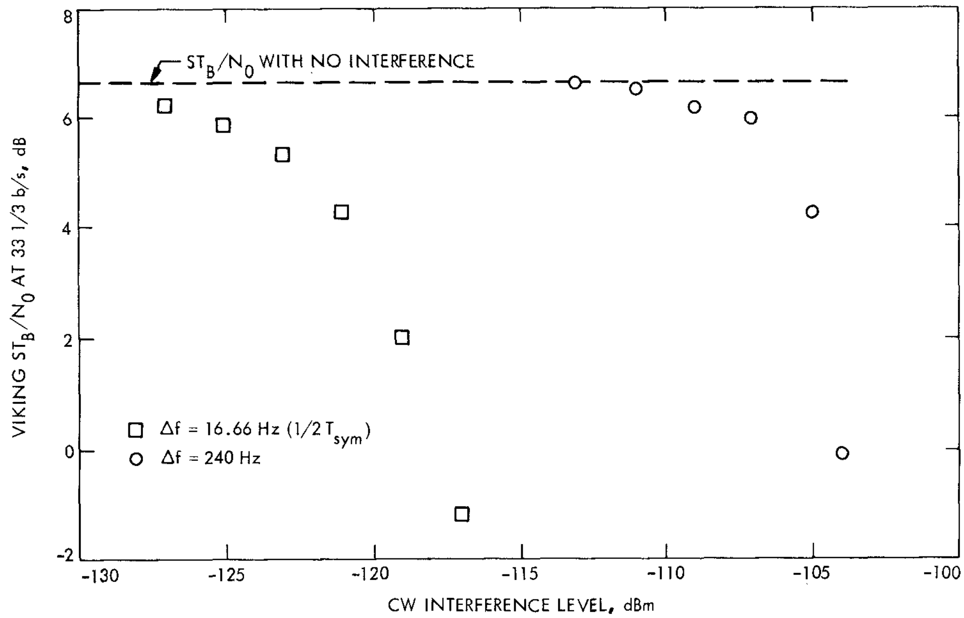


**Fig. 3. Measured cruise mode 33-1/3 b/s telemetry $ST_B/N_0$ degradation on channel 20 vs CW interfering level for various frequency offsets**

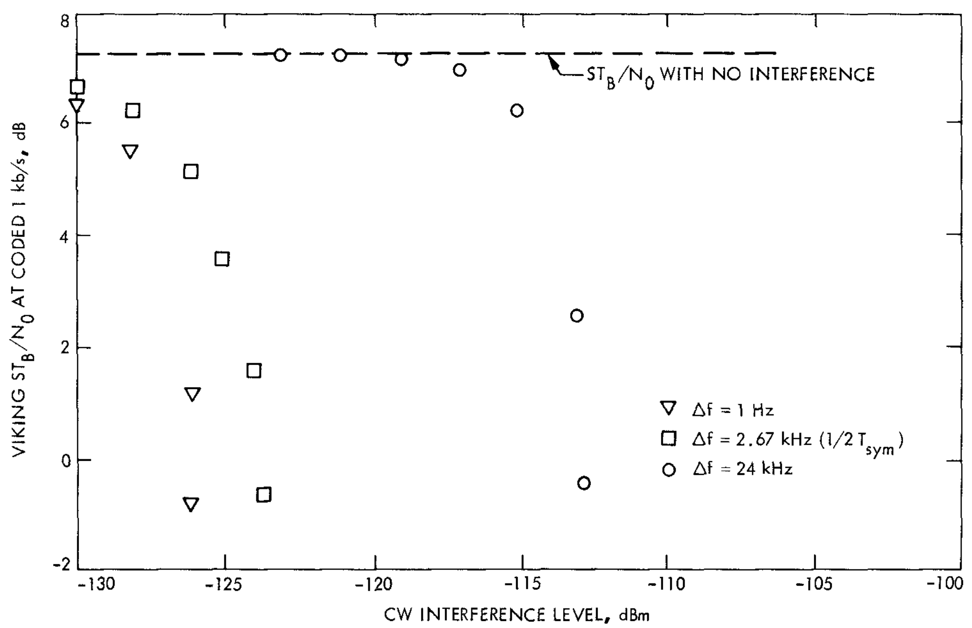


**Fig. 4. Measured coded 1-kb/s telemetry $ST_B/N_0$ degradation on channel 20 vs CW interfering level for various frequency offsets**

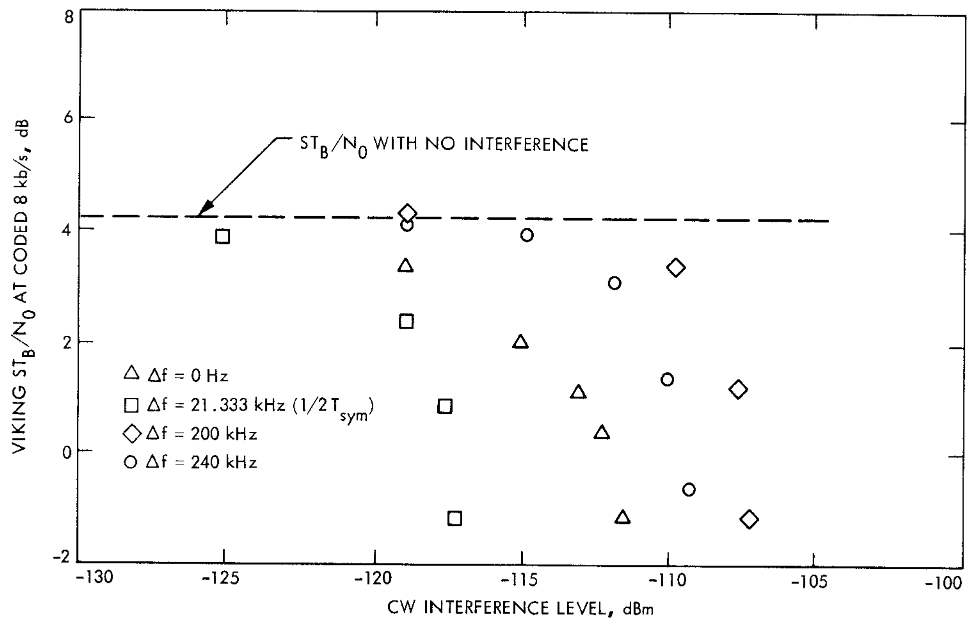


**Fig. 5. Measured coded 8-kb/s telemetry $ST_B/N_0$ degradation on channel 20 vs CW interfering level for various frequency offsets**

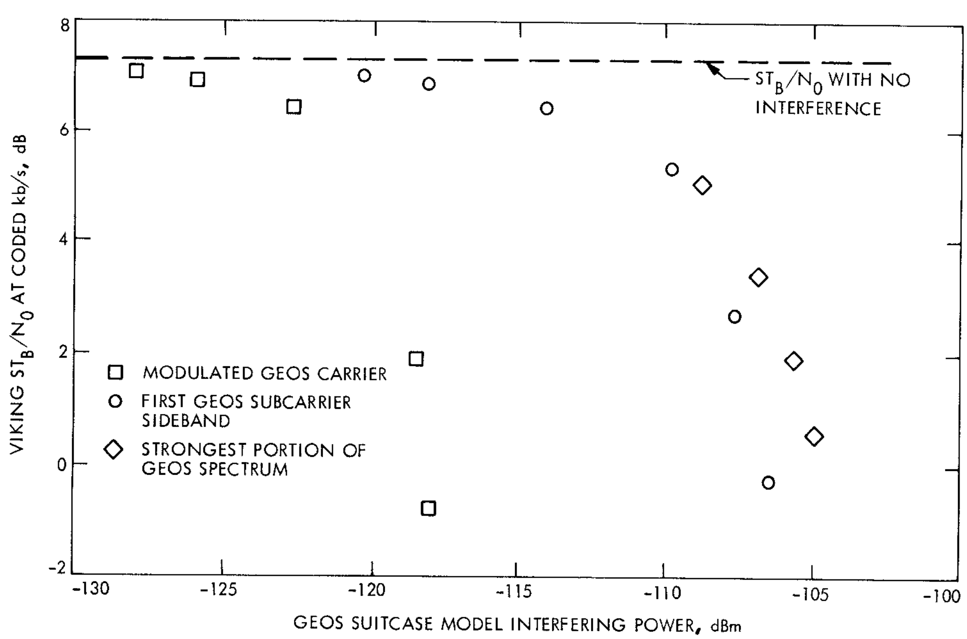


**Fig. 6. Measured coded 1-kb/s telemetry $ST_B/N_0$ degradation on channel 20 vs GEOS suitcase model interfering power for various portions of the interfering spectrum to produce harmonics at offset of half the Viking symbol rate (2.67 kHz)**

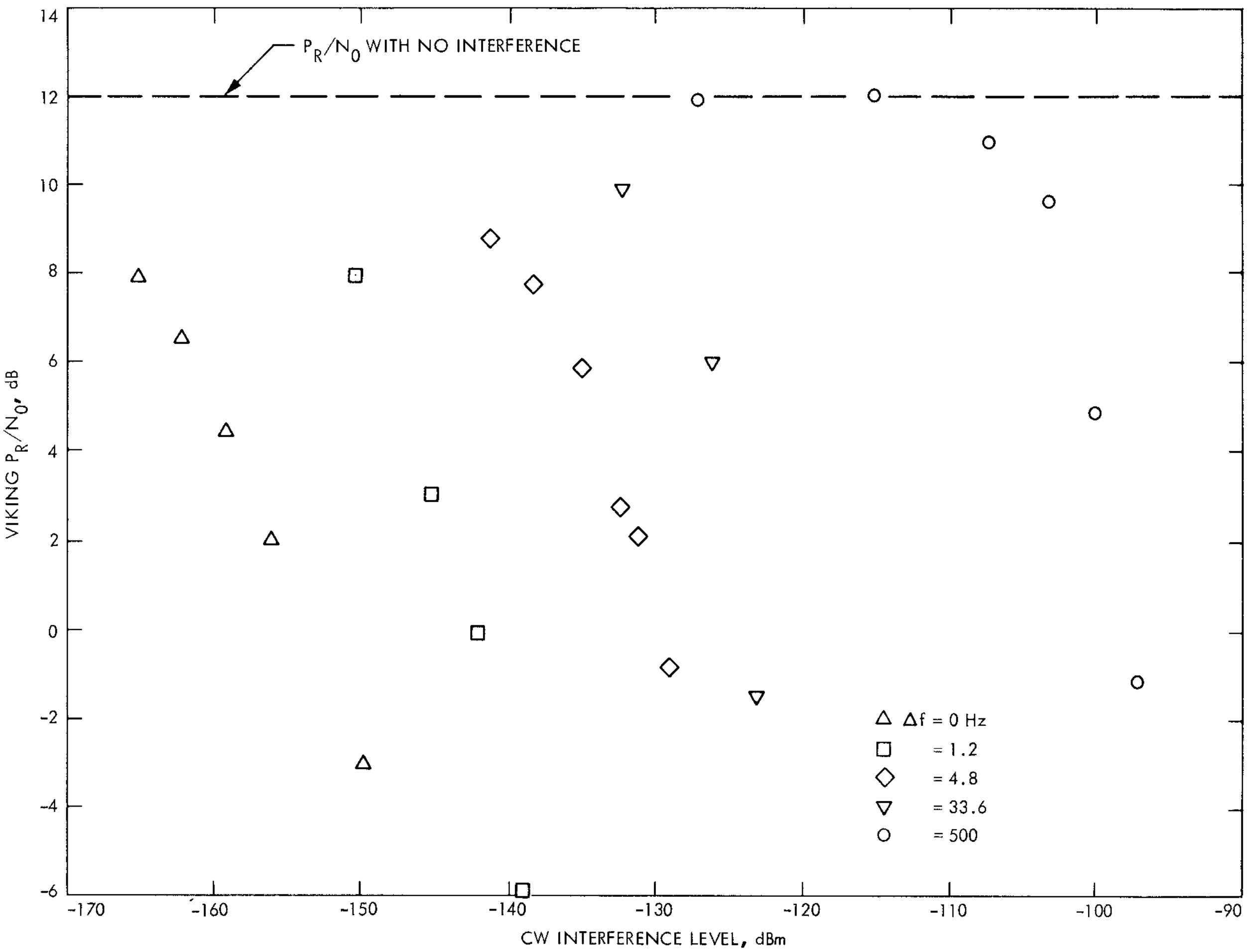


Fig. 7. Measured ranging $P_R/N_0$ degradation on channel 20 vs CW interfering level for various frequency offsets