W. W. Hansen Experimental Physics Laboratory
STANFORD UNIVERSITY
STANFORD, CALIFORNIA 94305 - 4085

Gravity Probe B Relativity Mission

SRE Special Linearity Test Analysis

S0654 Rev A

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Prepared by: J.M. Lockhart 6/5/2003
J.M. Lockhart Date

Approved by: G. M. Keiser 6/9/03
Mac Keiser, Chief Scientist Date

Approved by: Richard Whelan 6/5/2003
Systems Engineering Date

Approved by: 6/5/03
Quality Assurance Date

ITAR Assessment Performed T. Langenstein 6.9.03

ITAR Control Req'd? Yes (No)

Revision Record:

Revision A Update, June 04, 2003:
Updated to include T003 requirements that correspond to the SRE Spec requirements addressed in Rev. -. Updates indicated below with revision bars in the right hand margin. The original release of this document provided justification for accepting the SRE box-level performance. Both the original version and this update can be used to show that the SRE box-level performance is acceptable.

Original Release, Rev - , April 20, 2002

I. Purpose:

This document provides the analysis for the verification of SRE Specification Requirements 3.2.3.1.1.2.1, 3.2.3.1.1.2.2, and 3.2.3.1.1.2.3, which specify that the harmonic amplitude of harmonics 2-5 of each fundamental of a two-tone test signal of amplitude 90% of full scale and frequency >=100 Hz, and 2-10% of full scale at a frequency <= 0.1 Hz shall be less than, respectively, $1x10^{-4}$ (100 PPM) on Ranges 1&2, $1x10^{-1}$ (100000 PPM) on Range 3, and $1x10^{-1}$ (100000 PPM) on Range 4.

Revision A of this document includes the updates to the required harmonic amplitude per PCB 559 for the verification of T003 requirements 3.2.1.1 and 3.2.1.2.

T003 #3.2.1 Linearity
T003 #3.2.1.1 High Frequency
In the frequency range 100-1000 Hz the harmonic distortion of each of harmonics 2-5 of sinusoids with amplitude corresponding to the trapped flux levels of section 1.5 shall be less than 1.5e-4.
Verification Method: Test
T003 #3.2.1.2 Low Frequency
For frequencies less than 1 Hz, the harmonic distortion of each harmonic 2-5 of sinusoids with amplitude up to 80 arcsec London moment equivalent shall be less than 1.5e-4.
Verification Method: Analysis, Test

Note: for T003 #3.2.1.1 and 3.2.1.2, compliance must be shown when in the presence of the trapped flux levels of T003 #1.5 (9 microgauss).

PCB 559 : Value in both of the above have been changed from 1e-4 to 1.5e-4.

II. Results: (Tests run 2/18-19/02; specific data files listed on harmonic amplitude report sheets)

A. General Comments:

This report analyzes the results of the SRE Special Linearity Test, Procedure SRE-196. The forward A flight SRE was connected to a commercial Quantum Design SQUID and data was collected using the SRE data acquisition system. For the linearity test, a simulated gyro trapped flux signal of 137.5 Hz at an amplitude of 9.0 V out (1.94 flux quanta amplitude in Range 1, 5.73 flux quanta amplitude in Range 2, 13.2 flux quanta amplitude in Range 3 and in Range 4, the Test Current Source limited the maximum voltage out to an amplitude of 1.24V or 17.5 flux quanta) and a simulated London moment signal of 0.086 Hz at an amplitude of 0.15 V (0.03 flux quanta in

Range 1, 0.01 flux quanta in Range 2, 0.22 flux quanta in Range 3 and 2.1 flux quanta in Range 4) were injected.

The transfer functions for this arrangement were estimated (by Terry McGinnis, during test) to be

Range 1 4.63 V/flux quantum = 15173 counts/flux quantum
Range 2 1.57 V/flux quantum = 5145 counts/flux quantum
Range 3 0.68 V/flux quantum = 2215 counts/flux quantum
Range 4 0.071 V/flux quantum = 231 counts/flux quantum

[Note that the precise values for these transfer functions do not affect the linearity results since the fractional harmonic amplitudes are ratios of two signal amplitudes.]

The tests were run such that for the closed-loop linearity tests and the noise tests, two consecutive 5-minute data files were collected. For the Calibration linearity tests, two consecutive 15-minute files were collected. The first data CD contained, in general, only the first file of each two-file set. A second data CD received later contained the additional files.

The data all show a bleed-through signal at 10 Hz and harmonics thereof, with a high-frequency SQUID output waveform consisting of a sawtooth of amplitude 35 A-D counts p-p. This waveform is attenuated significantly by the 4 Hz lowpass filter in the low frequency chain, and shows up at low level (below one ADC count) in the low frequency channel output.

This test with only one flight box is representative of both flight boxes since the results are a function of box design only, and do not vary substantially for piece part differences. Design controls and functional testing ensures that the A and B versions are identical from a design and performance standpoint.

B. Conclusion

There were no failures relative to the new requirements; all SRE channels met both high and low frequency revised requirements.

The original linearity specs were met in most cases, but there were six failures; most of these failed by only a few percent on a linear scale, or less than one percent on a decibel (dB) scale. The worst case failure was 35% out of specification on a linear scale, 4% out on a dB scale. Original recommendations for the out of spec conditions are contained in section III.

C. Special Cases

Range 2 noise data (Proc, Step 10.3.16, File 20218232.026) suffered a 30 count flux jump about 20% of the way through the file.

Proc. 10.4.10 – Squid 1 Linearity, Range 3: Cal source was left active during linearity test, so signals at 1/62 Hz, .086 Hz, 137.5 Hz, and 220 Hz are all present.

Proc. 10.5.16 – Squid 1 Noise, Range 4: Cal source was left active during noise test, so signals at 1/62 Hz and 220 Hz are present.

D. Noise Levels (No Requirement for this test)

Low Frequency (.086 Hz), S1, R1: 6 $\mu\Phi/\sqrt{Hz}$ (Projects to 24 $\mu\Phi/\sqrt{Hz}$ at 0.005 Hz)

High Frequency, S1, R1: 1.8 $\mu\Phi/\sqrt{Hz}$ Corrupted by quantizing resolution.

E. Linearity Results

All of these pass new (PCB 559) requirements.

Linearity results, SQUID 1,Range 1, fractional harmonic distortion in PPM:
(Revised Req't: Fractional harmonic distortion of harmonics 2 through 5 less than 150 PPM)

	Hrm. 2	3	4	5
SQ LF	135	102	104	30
SQ HF	105	70	40	35

Calibration linearity results, SQUID 1, Range 1, fractional harmonic distortion in PPM:
(No requirement on performance.

	Hrm. 2	3	4	5
Source LF	370	38	90	40
Source HF	240	170	250	390
SQ LF	4000	2300	2250	1200
SQ HF	34000	54000	4100	5000

Linearity results, SQUID 1,Range 2, fractional harmonic distortion in PPM:
(Revised Req't: Fractional harmonic distortion of harmonics 2 through 5 less than 150 PPM)

	Hrm. 2	3	4	5
SQ LF	111	81	34	50
SQ HF	81	81	22	23

Calibration linearity results, SQUID 1, Range 2, fractional harmonic distortion in PPM:
(No requirement on performance)

	Hrm. 2	3	4	5
Source LF	370	38	88	46
Source HF	270	190	250	410
SQ LF	1080	570	690	620
SQ HF	240	133	339	350

Linearity results, SQUID 1,Range 3, fractional harmonic distortion in PPM:
(Revised Req't: Fractional harmonic distortion of harmonics 2 through 5 less than 15,000 PPM)

	Hrm. 2	3	4	5
SQ LF	105	109	26	16
SQ HF	62	217	17	30

Calibration linearity results, SQUID 1, Range 3, fractional harmonic distortion in PPM:
(No requirement on performance)

	Hrm. 2	3	4	5
Source LF	365	36	86	46
Source HF	270	190	250	410
SQ LF	1060	987	577	783
SQ HF	462	224	575	376

Linearity results, SQUID 1,Range 4, fractional harmonic distortion in PPM:
(Revised Req't: Fractional harmonic distortion of harmonics 2 through 5 less than 150,000 PPM)

	Hrm. 2	3	4	5
SQ LF	75	13	4	4
SQ HF	64	100	13	14

Linearity results, SQUID 3,Range 1, fractional harmonic distortion in PPM:
(Revised Req't: Fractional harmonic distortion of harmonics 2 through 5 less than 150 PPM)

	Hrm. 2	3	4	5
SQ LF	78	47	58	79
SQ HF	116	91	44	39

Calibration linearity results, SQUID 3, Range 1, fractional harmonic distortion in PPM:
(No requirement on performance)

	Hrm. 2	3	4	5
Source LF	380	50	123	14
Source HF	280	103	360	326
SQ LF	1080	570	690	620
SQ HF	240	133	339	350

Results sheets showing the harmonic amplitudes for each case are attached.

III. Recommendation/ Summary

The original version of this document provided a use-as-is recommendation for the areas where the SRE box-level requirements were not met. Based on the changes made for T003 3.2.1.1 and 3.2.1.2 per PCB 559, the acceptance of the box-level performance is confirmed.

T003 #3.2.1.1 High Frequency meets the revised requirement (PCB 559) with the following data (1.5e-4 equivalent to 150 PPM):

	Hrm. 2	3	4	5	Requirement
SQ1, Range 1	105	70	40	35	(1.5e-4 = 150 PPM)
SQ1, Range 2	81	81	22	23	(1.5e-4 = 150 PPM)
SQ1, Range 3	62	217	17	30	(Req't 15,000 PPM)
SQ1, Range 4	64	100	13	14	(Req't 150,000 PPM)
SQ3, Range 1	116	91	44	39	(1.5e-4 = 150 PPM)

T003 #3.2.1.2 Low Frequency meets the revised requirement (PCB 559) with the following data (1.5e-4 equivalent to 150 PPM):

	Hrm. 2	3	4	5	Requirement
SQ1, Range 1	135	102	104	30	(1.5e-4 = 150 PPM)
SQ1, Range 2	111	81	34	50	(1.5e-4 = 150 PPM)
SQ1, Range 3	105	109	26	16	(Req't 15,000 PPM)
SQ1, Range 4	75	13	4	4	(Req't 150,000 PPM)
SQ3, Range 1	78	47	58	79	(1.5e-4 = 150 PPM)