5.1.6.2 WAC FM NOISE CALIBRATION RESULTS

As reported in Reference 5.1.6.2-1

Reference 5.1.6.2-1 - IOM 388-PAG-CCA96-17, "WAC FM CALIBRATION RESULTS: COHERENT NOISE", C. Avis, December 6, 1996

5.1.6.2.1 INTRODUCTION

The Wide-angle Flight Model thermal/vacuum testing included the acquisition of a set of images at chamber temperatures of +25° C, +5° C and -10° C for detection of any patterns of coherent noise in the images. The term ‘coherent noise’ is used to mean noise signatures which occur at consistent spatial frequencies. These signature may have electrical sources or may be due to the CCD layout.

For the purposes of this analysis, there are two types of coherent noise. The term ‘fixed pattern noise’ describes coherent noise which has a fixed phase (i.e., it begins at the same pixel on every line). This is the type of noise which the eye/brain can easily pick out of an otherwise random image. ‘Fixed pattern noise’ may be present in either the horizontal direction or the vertical direction in images. Therefore, results of analysis for both directions is described below.

The term ‘electrical noise’ is used herein to describe coherent noise whose phase may be shifting (i.e., it may begin at a different pixel on every line). This type of noise is not readily visible by eye. This type would be expected only in the horizontal direction.

All frames in this analysis were flat-field (no target) frames. All summation modes and gain states are represented in the dataset and both antiblooming states were used. In addition, lossless compression was exercised.

5.1.6.2.2 METHOD 1 - Electrical Noise

A periodic signal can be introduced by the signal processing of the lines of pixels. Because the lines may not be processed at regular intervals, the phase of the periodic signal may vary from line to line. As the phase of the signal shifts, the amplitude at a given frequency should remain constant whereas the real and imaginary components are changing.

- Pick an area which is as clean as possible
- Filter with a large high-pass filter to dampen the low frequencies
- Rotate image area 90 degrees, if looking for patterns in the vertical direction
- Calculate Fourier Transform of the each line
- Calculate the amplitude as a function of frequency for each line
- For each frequency, calculate the mean amplitude using all lines and tabulate.

5.1.6.2.3 METHOD 2 - Fixed Pattern Noise

Some kinds of coherent noise will affect the same pixels on every line (or the same lines in every column). This is obviously the case if the source is in the CCD layout itself. Because the phase is constant, one can best isolate this signal from the random noise by averaging the signal in real-space rather that frequency-space.

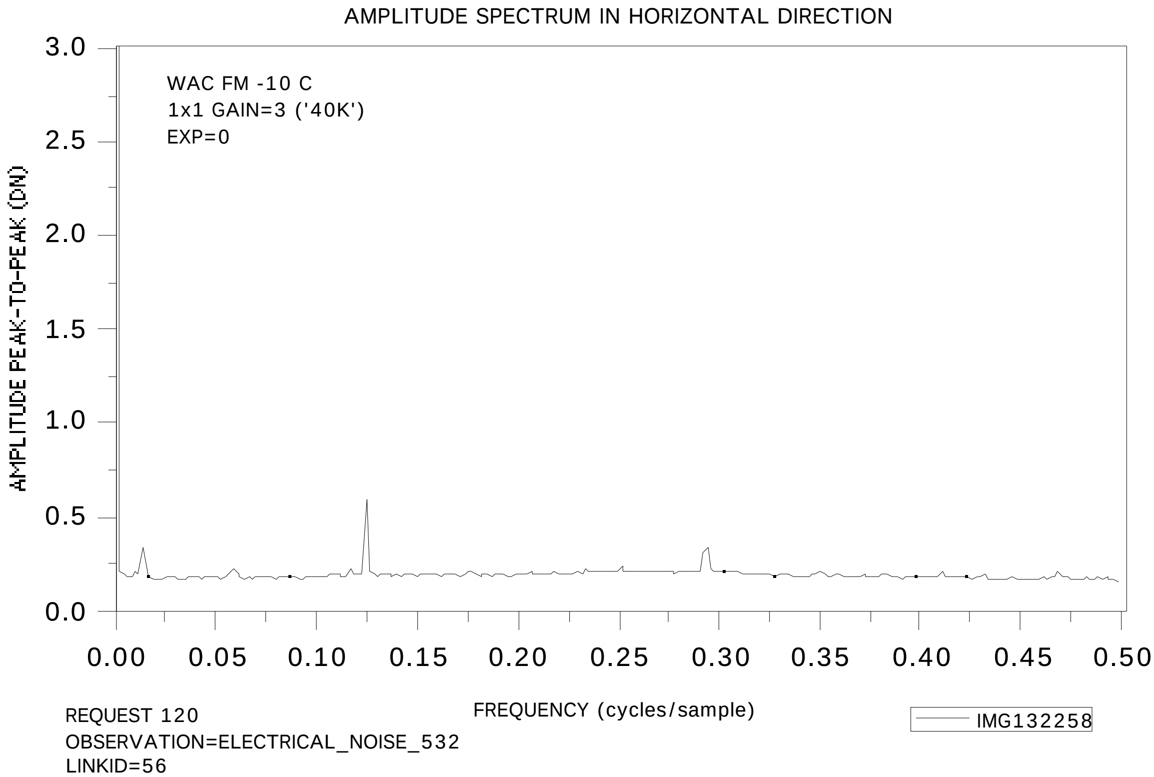
- Pick an area which is as clean as possible
- Rotate image area 90 degrees, if looking for patterns in the vertical direction
- Average the lines in the area
- Filter with a large high-pass filter to dampen the low frequencies
- Calculate Fourier Transform of the mean line
- Calculate the amplitude and tabulate vs. frequency

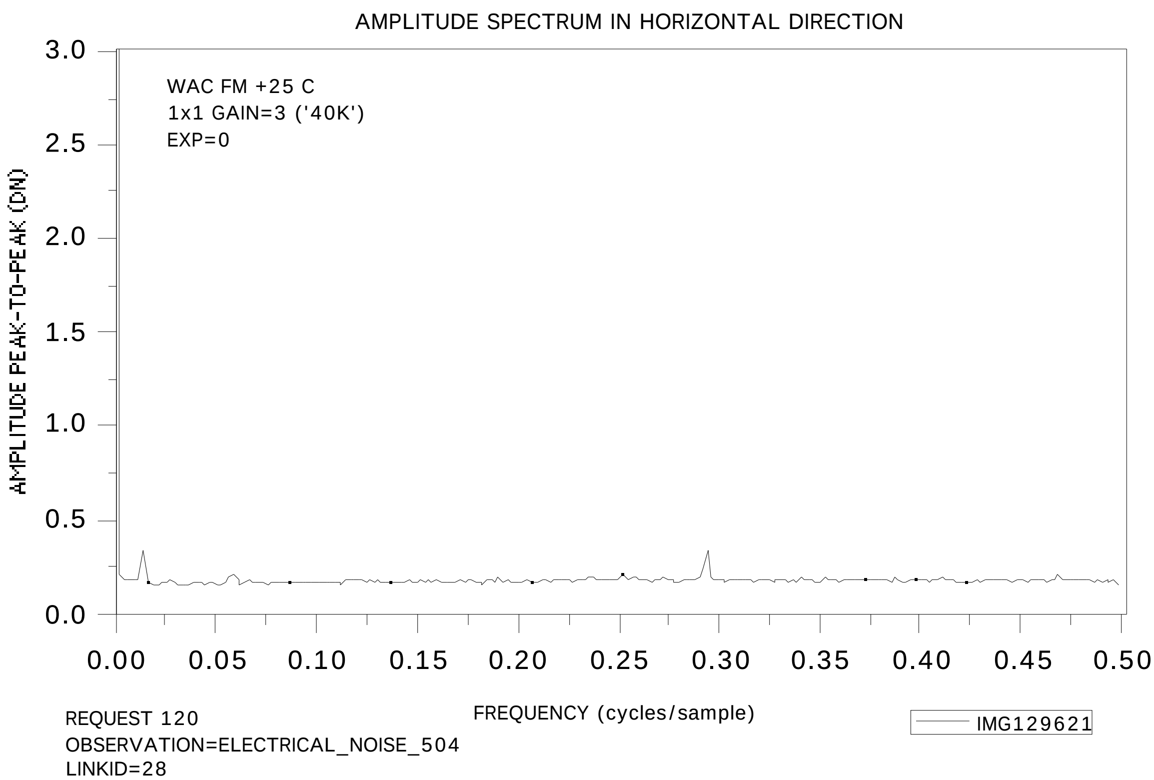
5.1.6.2.4 RESULTS

The following conclusions are drawn from this analysis.

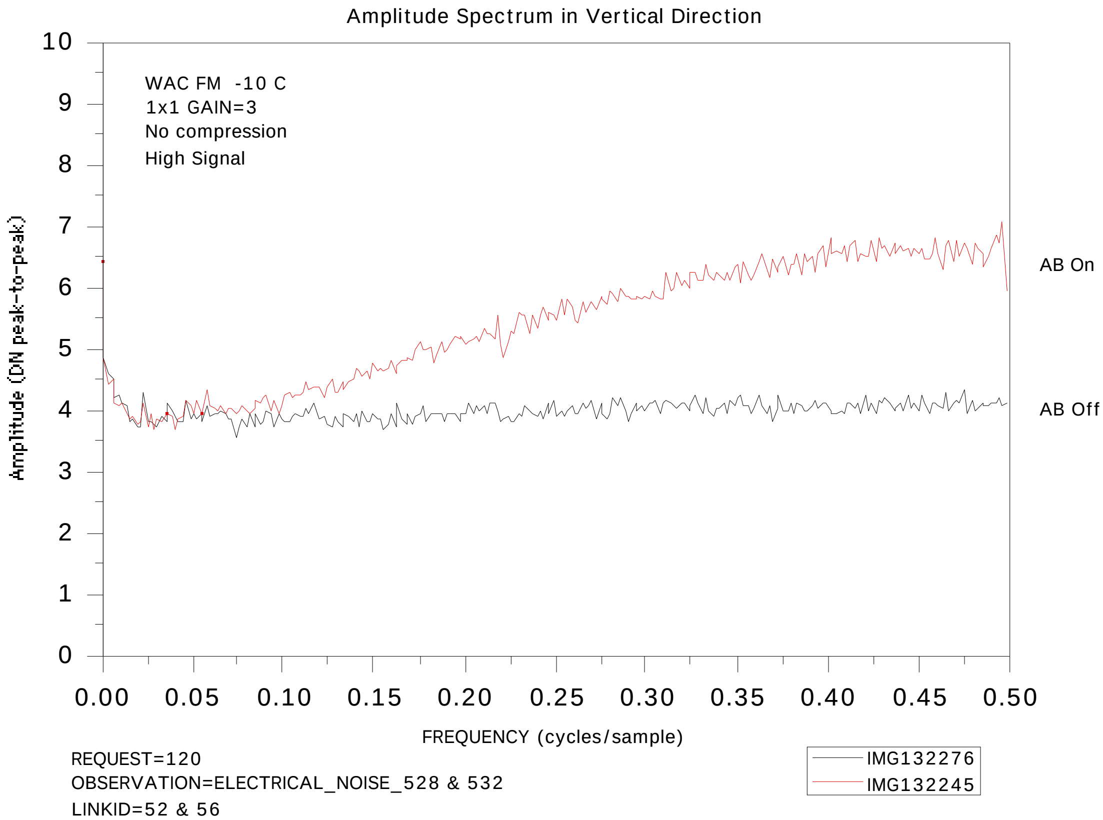
- The zero exposure frames have such low amplitude noise spectrum in the horizontal direction that the BIU transmission frequency peaks are detectable. The 0.25 DN peak in the horizontal spectrum at a frequency of 0.0136 is present in most images and and appears at about the same amplitude in all gains. The peak at 0.2938 is apparent in Gain 3, slightly in Gain 2 and not at all in Gain 1 or 0. The peak at 0.1245 may be environmental because it is not visible in all images. These peaks are seen in zero exposure frames but not in the lowest exposed frames available.
- The antiblooming state (‘ON’ or ‘OFF’) has a major effect on the spectrum of well-exposed frames. The amplitude of the frequencies greater than 0.1 cps is increased considerably in the vertical direction for the ‘ON’ case. The lower the signal the less this increase occurs.
- There is a significant fixed pattern noise vertically. Peaks occur at a frequency of 0.0233 and its harmonics. Zero exposure frames do not show the pattern, but exposed frames show it in all gain states. This is consistent with the “step-and-repeat” pattern of the CCD manufacturing process.
- There is also fixed pattern noise horizontally. The appearance of the spectrum from 0 cps to 0.1 cps (in 1x1 mode) is consistent and repeatable from frame to frame (exposed frames only). This set of features shows up (at lower-resolution) at the appropriate frequencies in the summation modes. This is probably due to the ”step-and-repeat” pattern of the CCD manufacturing process.
- No vertical electrical noise is apparent, as expected.
- The is no significant difference between data taken at the three temperatures.
- The LOSSLESS compression data is identical to that with no compression.

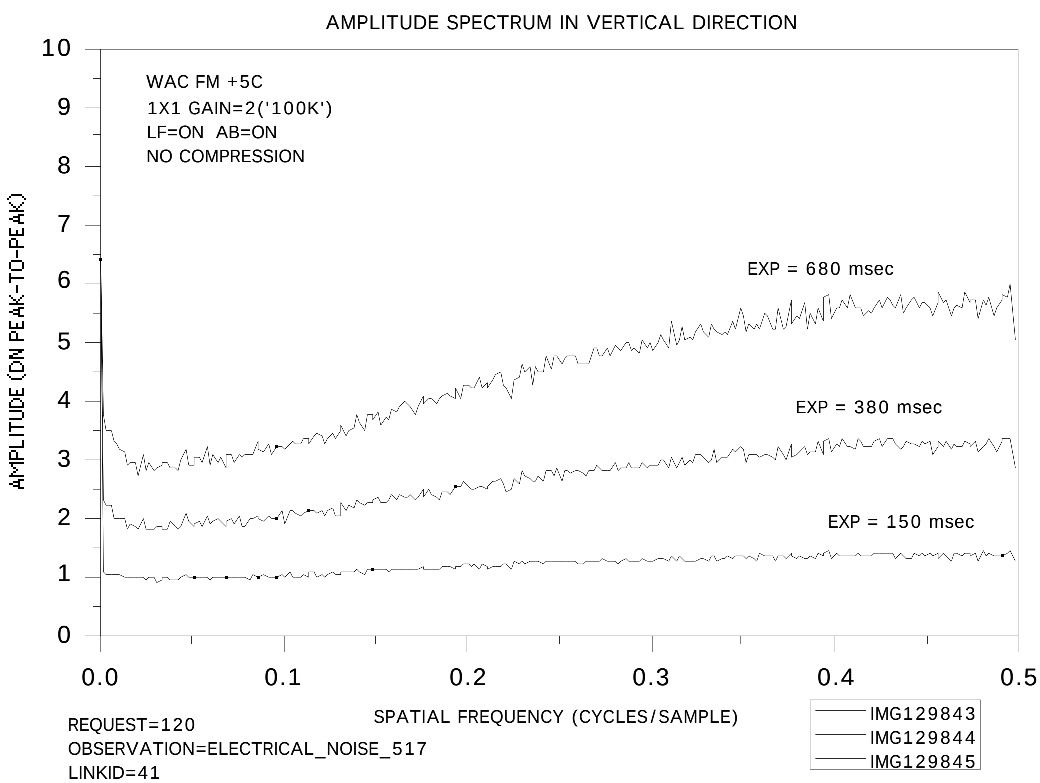
The following plots show the electrical noise spectrum at zero exposure for two frames. The peaks due to the BIU transmission frequency are visible. The 0.1245 peak comes and goes.



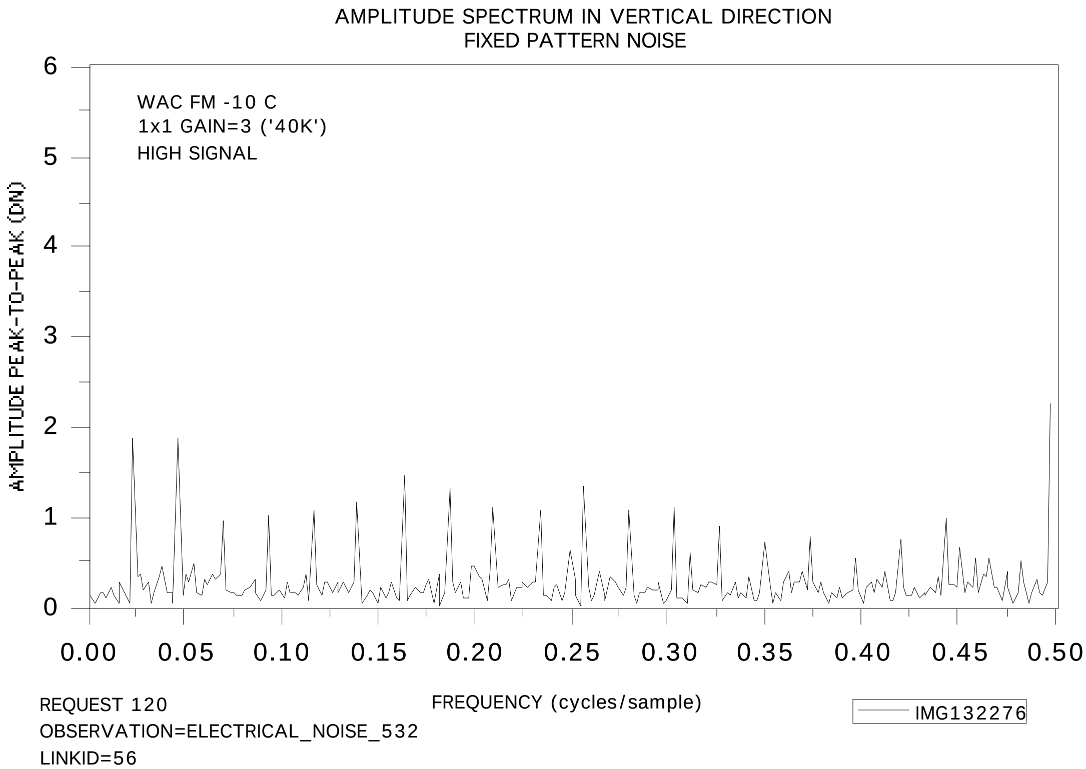


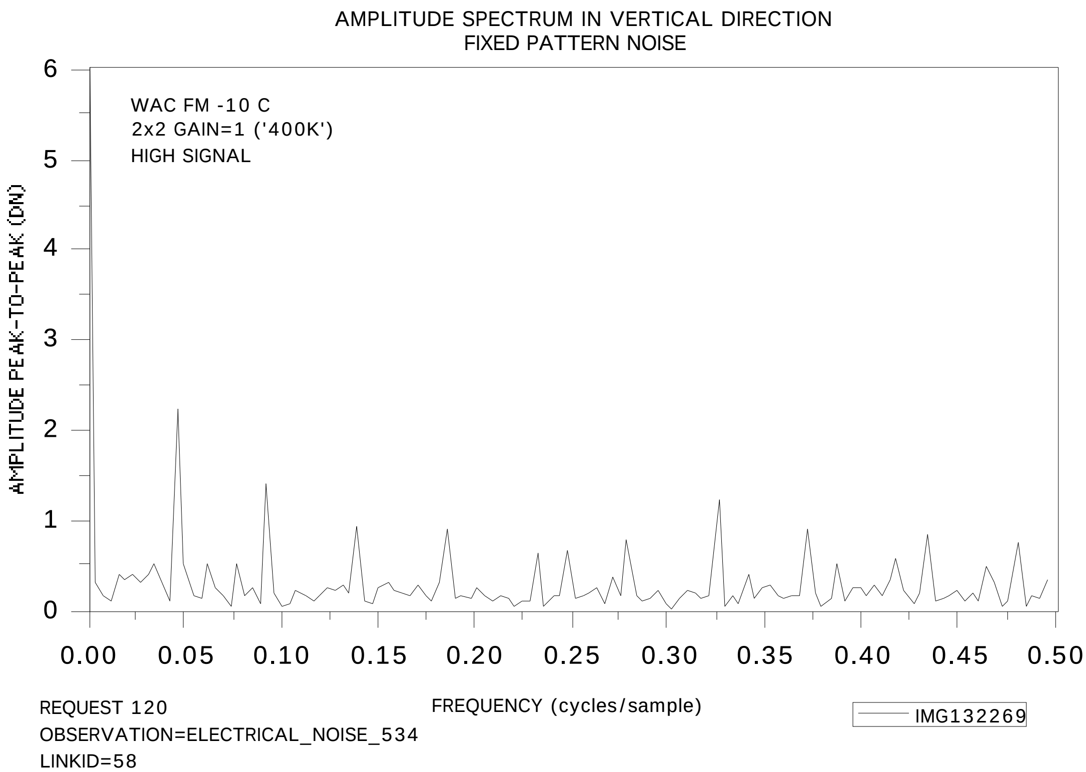
The following plots show the effect of Antiblooming on the spectrum.

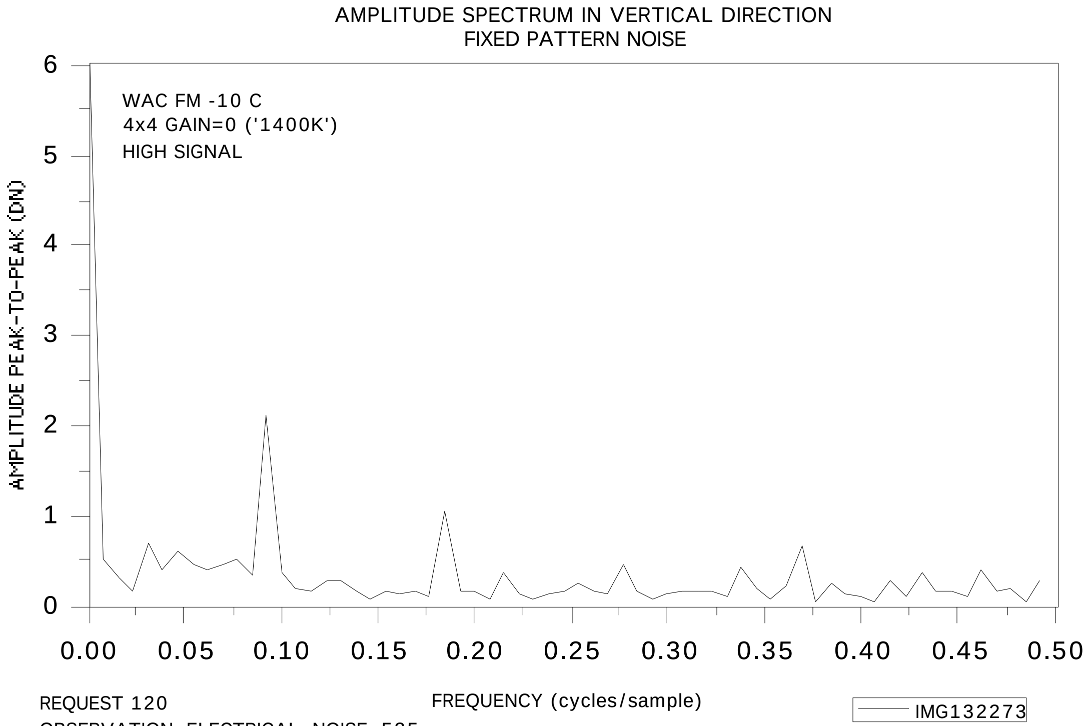




The following three plots show the vertical fixed pattern noise in each summation mode. This comes from the vertical component of the 'step-and-repeat' signature.

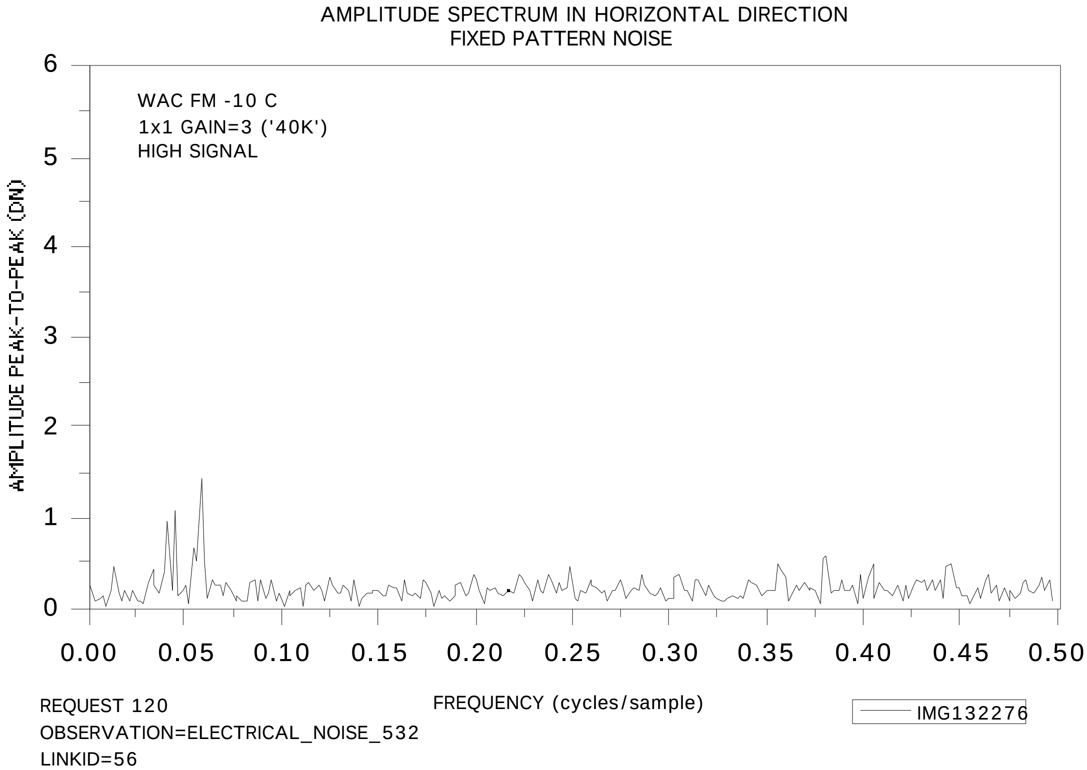


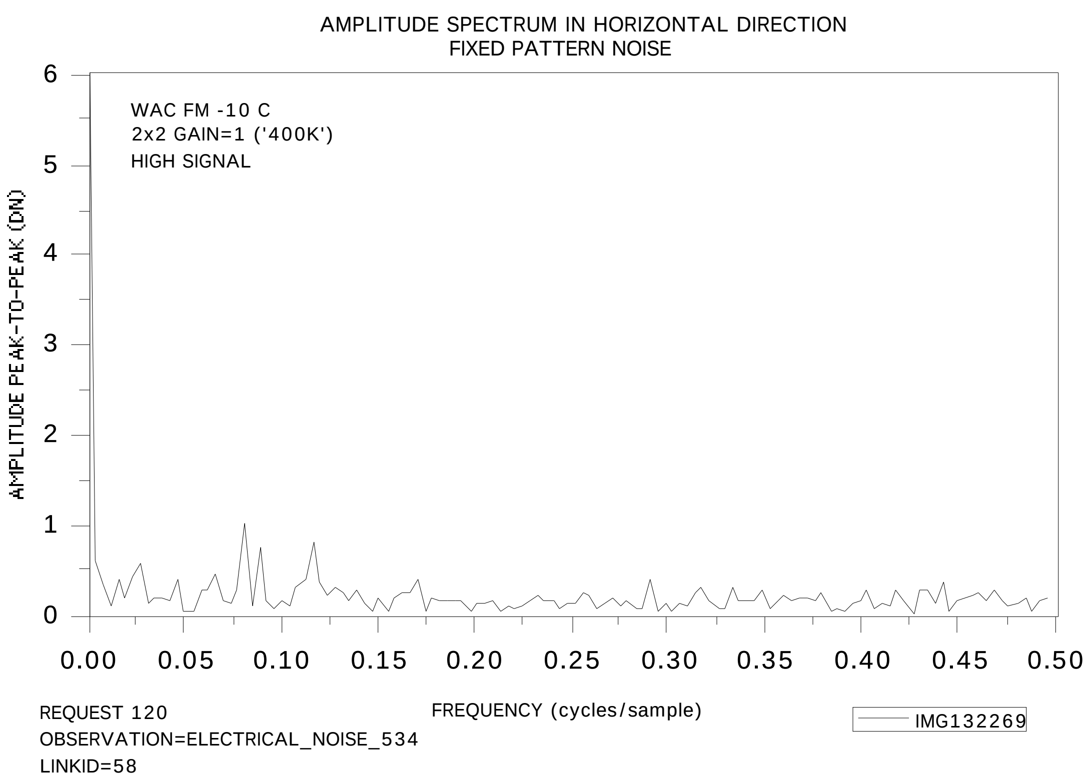


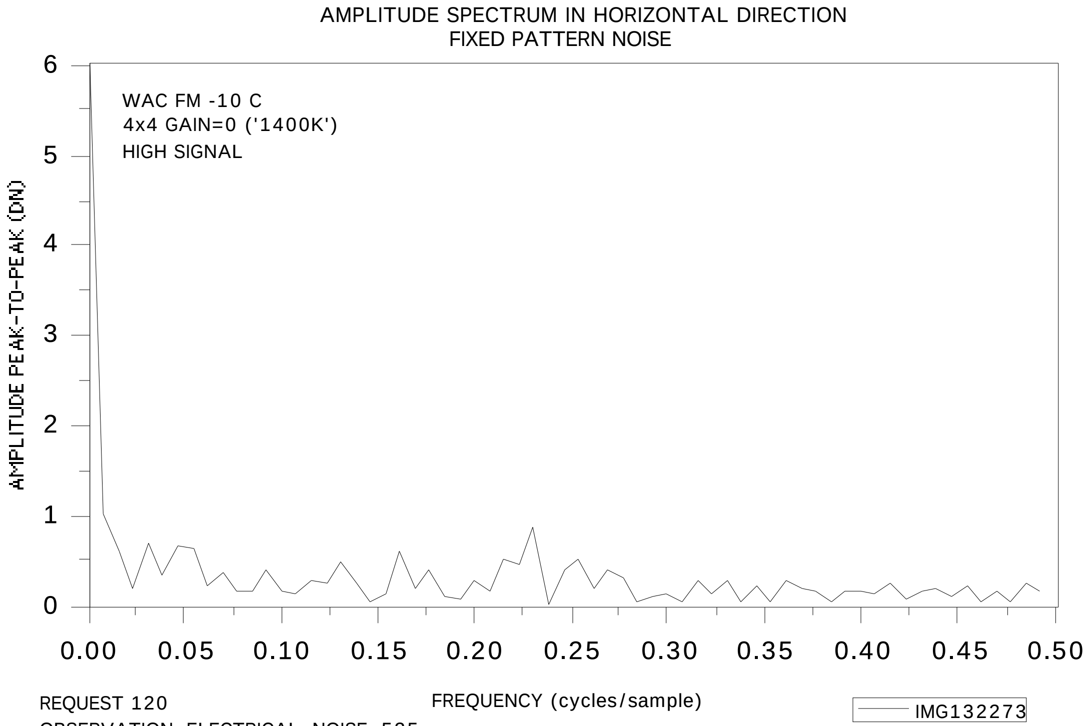


REQUEST 120
OBSERVATION=ELECTRICAL_NOISE_535
LINKID=59

The following three plots show the horizontal fixed pattern noise in each summation mode. This comes from the horizontal component of the 'step-and-repeat' signature.







REQUEST 120
OBSERVATION=ELECTRICAL_NOISE_535
LINKID=59

5.1.6.2.5 LIST OF FRAMES SUITABLE FOR COHERENT NOISE ANALYSIS

image	day	time	observation	gain	mode	expos
+25C AB=OFF LOSSLESS						
129605	193	5:8:38.0	ELECTRICAL_NOISE_500	3 (40K)	FULL	0
129606	193	5:9:37.0	ELECTRICAL_NOISE_500	3 (40K)	FULL	80
129607	193	5:10:36.0	ELECTRICAL_NOISE_500	3 (40K)	FULL	180
129608	193	5:11:35.0	ELECTRICAL_NOISE_500	3 (40K)	FULL	320
129609	193	5:12:43.0	ELECTRICAL_NOISE_501	2 (100K)	FULL	0
129610	193	5:13:42.0	ELECTRICAL_NOISE_501	2 (100K)	FULL	150
129611	193	5:14:41.0	ELECTRICAL_NOISE_501	2 (100K)	FULL	380
129612	193	5:15:40.0	ELECTRICAL_NOISE_501	2 (100K)	FULL	680
129613	193	5:16:48.0	ELECTRICAL_NOISE_502	1 (400K)	SUM2	0
129614	193	5:17:9.0	ELECTRICAL_NOISE_502	1 (400K)	SUM2	150
129615	193	5:17:30.0	ELECTRICAL_NOISE_502	1 (400K)	SUM2	320
129616	193	5:17:51.0	ELECTRICAL_NOISE_502	1 (400K)	SUM2	560
129617	193	5:18:21.0	ELECTRICAL_NOISE_503	0 (1400K)	SUM4	0
129618	193	5:18:36.0	ELECTRICAL_NOISE_503	0 (1400K)	SUM4	80
129619	193	5:18:51.0	ELECTRICAL_NOISE_503	0 (1400K)	SUM4	180
129620	193	5:19:6.0	ELECTRICAL_NOISE_503	0 (1400K)	SUM4	320
+25C AB=ON NOTCOMP						
129621	193	5:29:59.0	ELECTRICAL_NOISE_504	3 (40K)	FULL	0
129622	193	5:30:58.0	ELECTRICAL_NOISE_504	3 (40K)	FULL	80
129623	193	5:31:57.0	ELECTRICAL_NOISE_504	3 (40K)	FULL	180
129624	193	5:32:56.0	ELECTRICAL_NOISE_504	3 (40K)	FULL	320
129625	193	5:34:4.0	ELECTRICAL_NOISE_505	2 (100K)	FULL	0
129626	193	5:35:3.0	ELECTRICAL_NOISE_505	2 (100K)	FULL	150
129627	193	5:36:2.0	ELECTRICAL_NOISE_505	2 (100K)	FULL	380
129628	193	5:37:1.0	ELECTRICAL_NOISE_505	2 (100K)	FULL	680
129629	193	5:38:9.0	ELECTRICAL_NOISE_506	1 (400K)	SUM2	0
129630	193	5:38:30.0	ELECTRICAL_NOISE_506	1 (400K)	SUM2	150
129631	193	5:38:51.0	ELECTRICAL_NOISE_506	1 (400K)	SUM2	320
129632	193	5:39:12.0	ELECTRICAL_NOISE_506	1 (400K)	SUM2	560
129633	193	5:39:42.0	ELECTRICAL_NOISE_507	0 (1400K)	SUM4	0
129634	193	5:39:57.0	ELECTRICAL_NOISE_507	0 (1400K)	SUM4	80
129635	193	5:40:12.0	ELECTRICAL_NOISE_507	0 (1400K)	SUM4	180
129636	193	5:40:27.0	ELECTRICAL_NOISE_507	0 (1400K)	SUM4	320
+25C AB=OFF NOTCOMP						
129637	193	5:40:53.0	ELECTRICAL_NOISE_508	3 (40K)	FULL	0
129638	193	5:41:52.0	ELECTRICAL_NOISE_508	3 (40K)	FULL	80
129639	193	5:42:51.0	ELECTRICAL_NOISE_508	3 (40K)	FULL	180
129640	193	5:43:50.0	ELECTRICAL_NOISE_508	3 (40K)	FULL	320
129641	193	5:44:58.0	ELECTRICAL_NOISE_509	2 (100K)	FULL	0
129642	193	5:45:57.0	ELECTRICAL_NOISE_509	2 (100K)	FULL	150
129643	193	5:46:56.0	ELECTRICAL_NOISE_509	2 (100K)	FULL	380
129644	193	5:47:55.0	ELECTRICAL_NOISE_509	2 (100K)	FULL	680
129645	193	5:49:3.0	ELECTRICAL_NOISE_510	1 (400K)	SUM2	0
129646	193	5:49:24.0	ELECTRICAL_NOISE_510	1 (400K)	SUM2	150
129647	193	5:49:45.0	ELECTRICAL_NOISE_510	1 (400K)	SUM2	320
129648	193	5:50:6.0	ELECTRICAL_NOISE_510	1 (400K)	SUM2	560
129649	193	5:50:36.0	ELECTRICAL_NOISE_511	0 (1400K)	SUM4	0
129650	193	5:50:51.0	ELECTRICAL_NOISE_511	0 (1400K)	SUM4	80
129651	193	5:51:6.0	ELECTRICAL_NOISE_511	0 (1400K)	SUM4	180
129652	193	5:51:21.0	ELECTRICAL_NOISE_511	0 (1400K)	SUM4	320
+5C AB=OFF LOSSLESS						
129807	194	6:16:6.0	ELECTRICAL_NOISE_512	3 (40K)	FULL	0
129808	194	6:17:5.0	ELECTRICAL_NOISE_512	3 (40K)	FULL	80
129809	194	6:18:4.0	ELECTRICAL_NOISE_512	3 (40K)	FULL	180
129810	194	6:19:3.0	ELECTRICAL_NOISE_512	3 (40K)	FULL	320
129818	194	7:31:24.0	ELECTRICAL_NOISE_512	3 (40K)	FULL	0
129819	194	7:32:22.0	ELECTRICAL_NOISE_512	3 (40K)	FULL	80
129820	194	7:33:21.0	ELECTRICAL_NOISE_512	3 (40K)	FULL	180
129821	194	7:34:20.0	ELECTRICAL_NOISE_512	3 (40K)	FULL	320
129830	194	7:52:17.0	ELECTRICAL_NOISE_512	3 (40K)	FULL	0
129831	194	7:53:16.0	ELECTRICAL_NOISE_512	3 (40K)	FULL	80
129832	194	7:54:15.0	ELECTRICAL_NOISE_512	3 (40K)	FULL	180
129833	194	7:55:14.0	ELECTRICAL_NOISE_512	3 (40K)	FULL	320
129811	194	6:20:10.0	ELECTRICAL_NOISE_513	2 (100K)	FULL	0
129812	194	6:21:10.0	ELECTRICAL_NOISE_513	2 (100K)	FULL	150
129813	194	6:22:9.0	ELECTRICAL_NOISE_513	2 (100K)	FULL	380
129814	194	6:23:8.0	ELECTRICAL_NOISE_513	2 (100K)	FULL	680
129834	194	7:56:22.0	ELECTRICAL_NOISE_513	2 (100K)	FULL	0
129835	194	7:57:21.0	ELECTRICAL_NOISE_513	2 (100K)	FULL	150
129836	194	7:58:20.0	ELECTRICAL_NOISE_513	2 (100K)	FULL	380
129837	194	7:59:19.0	ELECTRICAL_NOISE_513	2 (100K)	FULL	680
129815	194	6:24:15.0	ELECTRICAL_NOISE_514	1 (400K)	SUM2	0
129816	194	6:24:36.0	ELECTRICAL_NOISE_514	1 (400K)	SUM2	150
129817	194	6:24:58.0	ELECTRICAL_NOISE_514	1 (400K)	SUM2	320
129822	194	7:35:0.0	ELECTRICAL_NOISE_514	1 (400K)	SUM2	0
129823	194	7:35:21.0	ELECTRICAL_NOISE_514	1 (400K)	SUM2	150
129824	194	7:35:42.0	ELECTRICAL_NOISE_514	1 (400K)	SUM2	320
129825	194	7:36:3.0	ELECTRICAL_NOISE_514	1 (400K)	SUM2	560
129826	194	7:36:33.0	ELECTRICAL_NOISE_515	0 (1400K)	SUM4	0
129827	194	7:36:48.0	ELECTRICAL_NOISE_515	0 (1400K)	SUM4	80
129828	194	7:37:3.0	ELECTRICAL_NOISE_515	0 (1400K)	SUM4	180
129829	194	7:37:18.0	ELECTRICAL_NOISE_515	0 (1400K)	SUM4	320
+5C AB=ON NOTCOMP						
129838	194	8:14:37.0	ELECTRICAL_NOISE_516	3 (40K)	FULL	0
129839	194	8:15:36.0	ELECTRICAL_NOISE_516	3 (40K)	FULL	80
129840	194	8:16:35.0	ELECTRICAL_NOISE_516	3 (40K)	FULL	180
129841	194	8:17:34.0	ELECTRICAL_NOISE_516	3 (40K)	FULL	320
129843	194	8:19:41.0	ELECTRICAL_NOISE_517	2 (100K)	FULL	150
129844	194	8:20:40.0	ELECTRICAL_NOISE_517	2 (100K)	FULL	380
129845	194	8:21:39.0	ELECTRICAL_NOISE_517	2 (100K)	FULL	680
129846	194	8:22:47.0	ELECTRICAL_NOISE_518	1 (400K)	SUM2	0
129847	194	8:23:8.0	ELECTRICAL_NOISE_518	1 (400K)	SUM2	150
129848	194	8:23:29.0	ELECTRICAL_NOISE_518	1 (400K)	SUM2	320
129849	194	8:23:50.0	ELECTRICAL_NOISE_518	1 (400K)	SUM2	560
129850	194	8:24:21.0	ELECTRICAL_NOISE_519	0 (1400K)	SUM4	0
129851	194	8:24:35.0	ELECTRICAL_NOISE_519	0 (1400K)	SUM4	80
129852	194	8:24:50.0	ELECTRICAL_NOISE_519	0 (1400K)	SUM4	180
129853	194	8:25:5.0	ELECTRICAL_NOISE_519	0 (1400K)	SUM4	320
+5C AB=OFF NOTCOMP						
129854	194	8:25:31.0	ELECTRICAL_NOISE_520	3 (40K)	FULL	0
129855	194	8:26:30.0	ELECTRICAL_NOISE_520	3 (40K)	FULL	80
129856	194	8:27:29.0	ELECTRICAL_NOISE_520	3 (40K)	FULL	180
129857	194	8:28:28.0	ELECTRICAL_NOISE_520	3 (40K)	FULL	320
129858	194	8:29:36.0	ELECTRICAL_NOISE_521	2 (100K)	FULL	0
129859	194	8:30:35.0	ELECTRICAL_NOISE_521	2 (100K)	FULL	150
129860	194	8:31:34.0	ELECTRICAL_NOISE_521	2 (100K)	FULL	380
129861	194	8:32:33.0	ELECTRICAL_NOISE_521	2 (100K)	FULL	680
129862	194	8:33:41.0	ELECTRICAL_NOISE_522	1 (400K)	SUM2	0
129863	194	8:34:2.0	ELECTRICAL_NOISE_522	1 (400K)	SUM2	150
129864	194	8:34:23.0	ELECTRICAL_NOISE_522	1 (400K)	SUM2	320
129865	194	8:34:44.0	ELECTRICAL_NOISE_522	1 (400K)	SUM2	560

129866	194	8:35:14.0	ELECTRICAL_NOISE_523	0	(1400K)	SUM4	0
129867	194	8:35:29.0	ELECTRICAL_NOISE_523	0	(1400K)	SUM4	80
129868	194	8:35:44.0	ELECTRICAL_NOISE_523	0	(1400K)	SUM4	180
129869	194	8:35:59.0	ELECTRICAL_NOISE_523	0	(1400K)	SUM4	320

-10C AB=OFF LOSSLESS

132277	201	7:52:41.0	ELECTRICAL_NOISE_524	3 (40K)	FULL	0
132278	201	7:53:40.0	ELECTRICAL_NOISE_524	3 (40K)	FULL	80
132279	201	7:54:39.0	ELECTRICAL_NOISE_524	3 (40K)	FULL	180
132280	201	7:55:38.0	ELECTRICAL_NOISE_524	3 (40K)	FULL	320
132281	201	7:56:46.0	ELECTRICAL_NOISE_525	2 (100K)	FULL	0
132282	201	7:57:45.0	ELECTRICAL_NOISE_525	2 (100K)	FULL	150
132283	201	7:58:44.0	ELECTRICAL_NOISE_525	2 (100K)	FULL	380
132284	201	7:59:43.0	ELECTRICAL_NOISE_525	2 (100K)	FULL	680
132285	201	8:0:51.0	ELECTRICAL_NOISE_526	1 (400K)	SUM2	0
132286	201	8:1:12.0	ELECTRICAL_NOISE_526	1 (400K)	SUM2	150
132287	201	8:1:33.0	ELECTRICAL_NOISE_526	1 (400K)	SUM2	320
132288	201	8:1:54.0	ELECTRICAL_NOISE_526	1 (400K)	SUM2	560
132289	201	8:2:24.0	ELECTRICAL_NOISE_527	0 (1400K)	SUM4	0
132290	201	8:2:40.0	ELECTRICAL_NOISE_527	0 (1400K)	SUM4	80
132291	201	8:2:54.0	ELECTRICAL_NOISE_527	0 (1400K)	SUM4	180
132292	201	8:3:9.0	ELECTRICAL_NOISE_527	0 (1400K)	SUM4	320

-10C AB=ON NOTCOMP

132242	201	7:3:54.0	ELECTRICAL_NOISE_528	3 (40K)	FULL	0
132243	201	7:4:53.0	ELECTRICAL_NOISE_528	3 (40K)	FULL	80
132244	201	7:5:52.0	ELECTRICAL_NOISE_528	3 (40K)	FULL	180
132245	201	7:6:51.0	ELECTRICAL_NOISE_528	3 (40K)	FULL	320
132246	201	7:7:59.0	ELECTRICAL_NOISE_529	2 (100K)	FULL	0
132247	201	7:8:58.0	ELECTRICAL_NOISE_529	2 (100K)	FULL	150
132248	201	7:9:57.0	ELECTRICAL_NOISE_529	2 (100K)	FULL	380
132249	201	7:10:56.0	ELECTRICAL_NOISE_529	2 (100K)	FULL	680
132250	201	7:12:4.0	ELECTRICAL_NOISE_530	1 (400K)	SUM2	0
132251	201	7:12:25.0	ELECTRICAL_NOISE_530	1 (400K)	SUM2	150
132252	201	7:12:46.0	ELECTRICAL_NOISE_530	1 (400K)	SUM2	320
132253	201	7:13:7.0	ELECTRICAL_NOISE_530	1 (400K)	SUM2	560
132254	201	7:13:37.0	ELECTRICAL_NOISE_531	0 (1400K)	SUM4	0
132255	201	7:13:52.0	ELECTRICAL_NOISE_531	0 (1400K)	SUM4	80
132256	201	7:14:7.0	ELECTRICAL_NOISE_531	0 (1400K)	SUM4	180
132257	201	7:14:22.0	ELECTRICAL_NOISE_531	0 (1400K)	SUM4	320

-10C AB=OFF NOTCOMP

132258	201	7:14:48.0	ELECTRICAL_NOISE_532	3 (40K)	FULL	0
132274	201	7:35:52.0	ELECTRICAL_NOISE_532	3 (40K)	FULL	80
132275	201	7:36:51.0	ELECTRICAL_NOISE_532	3 (40K)	FULL	180
132276	201	7:37:50.0	ELECTRICAL_NOISE_532	3 (40K)	FULL	320
132262	201	7:19:4.0	ELECTRICAL_NOISE_533	2 (100K)	FULL	0
132263	201	7:20:3.0	ELECTRICAL_NOISE_533	2 (100K)	FULL	150
132264	201	7:21:2.0	ELECTRICAL_NOISE_533	2 (100K)	FULL	380
132265	201	7:22:1.0	ELECTRICAL_NOISE_533	2 (100K)	FULL	680
132266	201	7:23:9.0	ELECTRICAL_NOISE_534	1 (400K)	SUM2	0
132267	201	7:23:30.0	ELECTRICAL_NOISE_534	1 (400K)	SUM2	150
132268	201	7:23:51.0	ELECTRICAL_NOISE_534	1 (400K)	SUM2	320
132269	201	7:24:12.0	ELECTRICAL_NOISE_534	1 (400K)	SUM2	560
132270	201	7:24:45.0	ELECTRICAL_NOISE_535	0 (1400K)	SUM4	0
132271	201	7:25:0.0	ELECTRICAL_NOISE_535	0 (1400K)	SUM4	80
132272	201	7:25:15.0	ELECTRICAL_NOISE_535	0 (1400K)	SUM4	180
132273	201	7:25:30.0	ELECTRICAL_NOISE_535	0 (1400K)	SUM4	320