NATIONAL RADIO ASTRONOMY OBSERVATORY

25-METER MM WAVE TELESCOPE MEMO # 82

The First Look at the Schaevitz Inclinometer

1. Introduction

Since writing Memos #69 and #70, we have received a Schaevitz inclinometer. It has the following specifications:

Type: LSOC S/N: 3756
Range: ± 14.5 degrees
Output at full range: ± 5 volts
Power required: ± 15 volts, 50 Ma.

This note describes the tests made on the system noise. The specification says that the noise output is "2 mV RMS maximum (random noise)". It might thus be that this noise limits the performance of the inclinometer. Two types of test have been made on this noise, and this note describes the results.

2. The Noise Spectrum

The inclinometer output, which is of course a DC voltage with a small superimposed noise component, was first examined with a good oscilloscope. The noise looked like noise, except when the support on which the LSOC stood was disturbed. Then outputs of various frequencies could be generated. It was not clear whether these depended on the vibration frequencies of the LSOC support or on the LSOC itself.

At Green Bank there is an excellent instrument for measuring the spectrum of this type of noise. Its characteristics are:

Maker: Federal Scientific, New York
Model: UA 14-A Ubiquitous Spectrum Analyzer and Spectrum Averager
Frequency Range Used: 0-200 Hz

Bandwidth (3 dB) on this range: 0.8 Hz
Sample rate on this range: 600 per second
No. of spectra averaged: 16
Sensitivity (using the NRAO-built back-off amplifier): A few microvolts.

With this it was possible to measure and record the LSOC noise spectrum. Figure 1 shows the results. The vertical scale is linear in voltage, and the scale was calibrated in volts RMS using the built-in calibration.

Figure 1(a) is with the LSOC very near the strong concrete floor of the laboratory basement; it was placed on the footing of one of the columns supporting the test track.

Figure 1(b) is with the LSOC on the heavy granite slab at the start of the track.

Several such spectra were taken, at various frequency ranges. Single spectra and averages of up to 16 were recorded.

Figure 1(a) shows that the noise is well-behaved under stable mounting conditions. Figure 1(b) shows that specific frequencies can get enhanced under certain mounting conditions. In particular, frequency peaks show at 21 Hz, 32 Hz, 87 Hz, and 120 Hz.

The spectrum of 1(a) suggests that Schaevitz over-estimate the LSOC noise, but the following experiment shows this more clearly.

3. <u>The Magnitude of the Noise</u>

It was easy to sample the LSOC noise output, write the samples onto tape and process them in the IBM 360 at Charlottesville. Sampling rates up to 100 Hz could be used, and the digitizing system gave one bit for a LSOC voltage change of 314 microvolts. So it could be used to study the RMS noise fluctuations down to about the 100 microvolt level. This, for the $\pm$ 14.5° inclinometer, corresponds to any angle change of 1.0 arc seconds, and would easily meet our needs.

Several runs were made in which 6000 noise samples were taken. These were then converted into voltages, averaged in blocks of 200 and the one sigma S.D. of each block found. This gives a measure of the S.D. of a single sample. Then, from the 30 average values a 1σ S.D. of the average values was found. If the noise is well-behaved, one would expect the S.D. of the averages to be $\sqrt{200}$ or 14.14 times smaller than the S.D. of a single sample.

Table I shows the results of 2 such tests (only 10 of the 30 blocks are included in Table I).

Table I. Sampling the LSO Noise

	#4 Run of March 15		#1 Run of March 23	
Counts	Mean Volts	RMS Microvolts	Mean Millivolts	RMS Microvolts
1-200	1.07002	261	56.54	657
601-800	1.06998	276	56.54	667
1201-1400	1.06996	251	56.56	684
1801-2000	1.06995	255	56.56	698
2401-2600	1.06996	268	56.54	693
3001-3200	1.06998	272	56.51	685
3601-3800	1.06998	282	56.51	707
4201-4400	1.06998	271	56.59	685
4801-5000	1.06997	258	56.56	685
5401-5600	1.07000	267	56.55	683

If we now compute the mean value for each set of 30 blocks of 200 and its S.D., we get:

#4 of March 15 Mean voltage = 1.06997±19 microvolts

#1 of March 23 Mean millivolts = 56.555± 25 microvolts

We first note that the March 23 run has a higher RMS for a single sample. This is due to an observable periodic disturbance during that run, not observed during the March 15 run (see Figure 2). Nevertheless, the RMS of the means of the blocks is 25 microvolts as compared to 19, showing that this effect did, in fact, average out.

The mean RMS on the March 15 run was 261 microvolts and 261/14.14 = 18.5, showing that the noise in that run was well-behaved. The March 23 run, with its periodic component, would not be expected to show such agreement.

4. Conclusions

a) The manufacturer appears to over-estimate the noise in the inclinometer output by a factor of about 10.

b) It appears likely that by a suitable choice of sampling and averaging the inclinometer noise can be reduced below 1 arc second in a time of the order of 1 second.

c) The behaviour of the telescope structure and its effect on the inclinometer is likely to be of vital importance to the success of the method for measuring surfaces.

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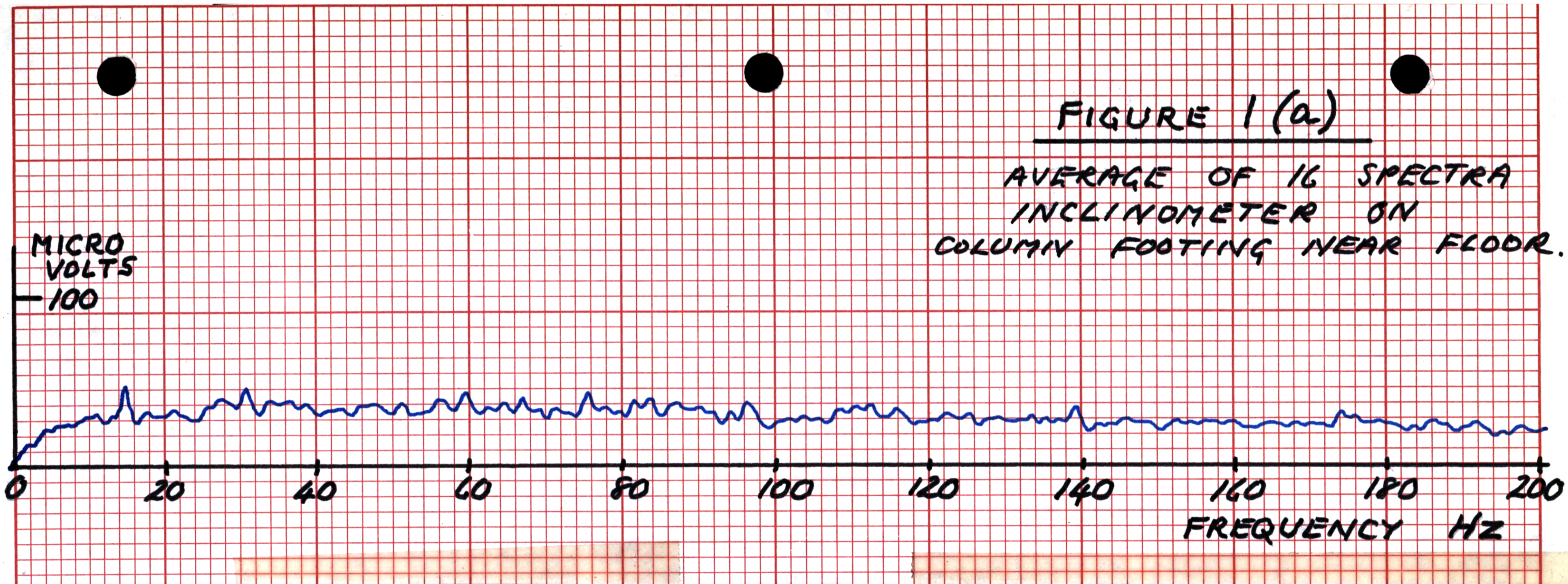


FIGURE 1 (a)
AVERAGE OF 16 SPECTRA
INCLINOMETER ON
COLUMN FOOTING NEAR FLOOR.
MICRO VOLTS
100
0
20
40
60
80
100
120
140
160
180
200
FREQUENCY Hz

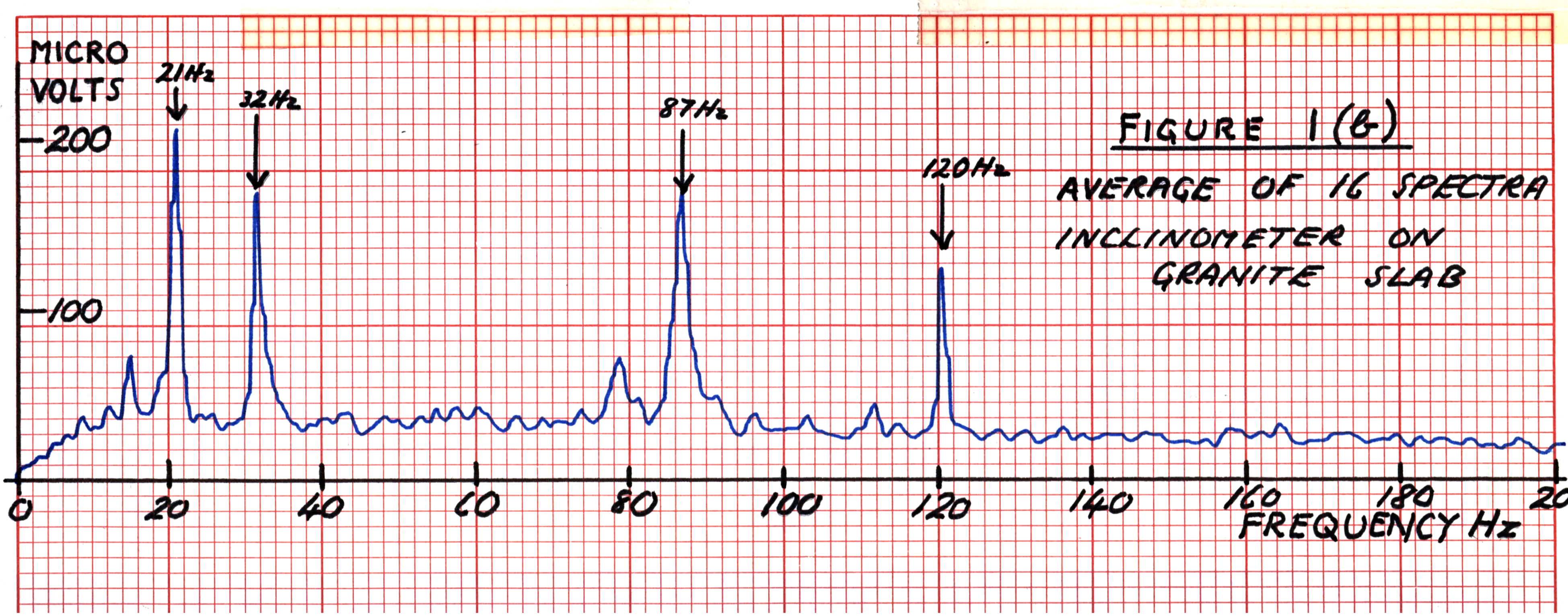
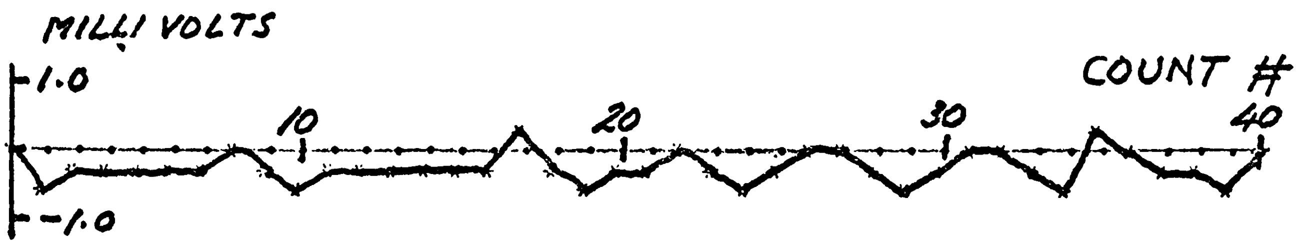
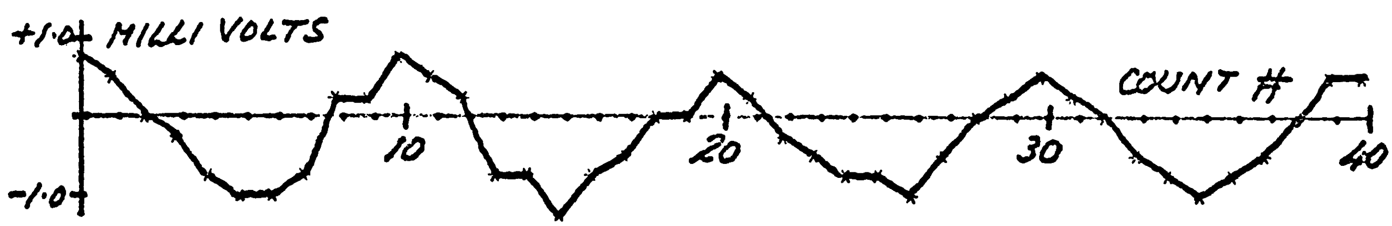


FIGURE 1 (b)
AVERAGE OF 16 SPECTRA
INCLINOMETER ON
GRANITE SLAB
MICRO VOLTS
200
100
21Hz
32Hz
87Hz
120Hz
0
20
40
60
80
100
120
140
160
180
200
FREQUENCY Hz



RUN #4 OF MARCH 15.



RUN #1 OF MARCH 23

FIGURE 2

THE FIRST 40 COUNTS OF THE INCLINOMETER OUTPUT