Stability Comparison of Three Frequency Synthesizers

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The HP 5100A/5110A, Dana 7030, and Fluke 644A synthesizers were evaluated to determine the typical drift and stability that can be expected in a control room environment. All synthesizers were judged equal in short-term drift, and the Dana synthesizer was found to be superior in long-term drift. The HP and the Dana synthesizers were the most stable, while the Fluke synthesizers did not perform reliably.

I. Introduction

The HP 5100A/5110A (0–50 MHz), Dana 7030 (0–11 MHz), and Fluke 644A (0–40 MHz) synthesizers were tested at 5 MHz to determine the typical drift and stability that can be expected in a control room environment. Measurements were taken at normal laboratory room temperatures of 20 to 25°C. The synthesizers were standard units used in the laboratory. A total of eight test runs, numbered in chronological order, were made using the same synthesizers throughout the testing (except the Fluke which eventually failed and required a replacement). By testing two synthesizers simultaneously during each run it was possible to: (1) accurately compare the performance under identical conditions of temperature and electrical disturbance, (2) differentiate between intrinsic and systematic errors in the data and, (3) measure the repeatability of the data, since one unit of the pair would always appear in a subsequent run. Over 245 h of data were taken; the long-term runs averaged about 50 h and the short-term runs required less than an hour to determine the phase shift in a 100-sec interval.

II. System Description

Noise and drift are minimized in the phase detection scheme of Fig. 1 by using Schottky barrier diode double balanced mixers with about a 600 mV p-p S-curve. The 1-kHz filter preceding the chart recorder determines the noise bandwidth. The required 90-deg phase shift between the mixer ports is obtained by using the synthesizer's search control to vary the frequency until a dc null appears at the mixer output, whereupon the search oscillator is switched out, locking in the 90-deg phase shift. The distribution amplifier that supplies the cesium reference has low noise and is AGC'd to minimize AM to PM conversion.

III. Results

Test results are shown in Tables 1 and 2. A section taken from run 8 (Fig. 2) is representative of the long-term runs and shows the diurnal variations of phase with temperature, including two spontaneous perturbations generated by the Fluke synthesizer 2. The first Fluke failed after the fourth run by shifting 5 to 6 Hz off frequency at 5 MHz, therefore making the previous data suspect. The second Fluke, the replacement unit, performed satisfactorily until the last run when two perturbations were observed and were assumed to be internally generated, since corresponding fluctuations did not appear in the adjacent phase plot of the Dana. The Dana's poorest stability occurred at 6:00 pm on Feb. 14, 1971 due to a thermal transient that affected both synthesizers. The Fluke was affected to a lesser extent because of its large thermal mass. Interestingly, during run 5, no phase deviations were detected from the HP or the Dana synthesizers during the severe California earthquake of February 9.

Run 6 (Fig. 3) shows the short-term drift and high-frequency noise of the Dana and HP synthesizers. The initial runs had been somewhat inconsistent; so, beginning with run 5, ground loops were carefully controlled and a Wanlass PD-1410 power line conditioner was added that provided 60 dB isolation of the measurement system from line transients. This improved the data and eliminated large unexplainable data fluctuations in the long-term runs. Even with these precautions the data was slightly more stable during the weekends when there was less activity.

Run 6 also shows that the HP synthesizer exhibited greater high-frequency noise (around 1 Hz) than the Dana. In Ref. 1, p. 58 the phase noise for the Fluke in the 4-100 Hz spectrum was found to be about 6 dB less than the Dana and the HP. Since the Dana uses a digital counting technique in the phase-locked loop of the synthesizer, it was suspected that certain frequency settings on the front panel could cause unusual digital patterns rippling in the phase register and result in a substantial increase of the phase noise. Upon investigation the maximum change in phase noise in a 5 to 100 Hz bandwidth was less than ½ dB when switching from 5,000,000 to 5,000,001 Hz.

IV. Conclusions

Short-term drift. All synthesizers exhibited about the same short-term drift.

Total drift. The Dana exhibited about 2.5 times less drift than the HP and 6.5 times less drift than the Fluke.

Stability. The Dana and the HP exhibited about the same stability but were 5 times more stable than the Fluke.

High-frequency noise. (Centered around 1 Hz) The Dana and the Fluke were about the same but exhibited 5 times less high frequency noise than the HP.

Power line conditioning. It was not determined that power line transients were actually affecting synthesizer phase stability and it is suspected that line conditioning improved the data by merely isolating the voltage sensitive elements of the measuring system.

Reliability. The first Fluke synthesizer failed after the fourth run and its replacement, Fluke 2, produced a spontaneous phase perturbation in the eighth run that reduced the overall stability to 65 times less than the Dana synthesizer.

It was noted during the testing that the Dana selector switches can apparently become dirty and increase the phase noise two to three times. A similar problem has been noted with the HP's wherein the selector switches will not make contact when depressed and repeated actuation is required to successfully operate the switch. Conclusions are summarized in Table 3.

Reference

1. Meyer, R., and Sward, A., "Frequency Generation and Control: The Measurement of Phase Jitter," in *The Deep Space Network*, Space Programs Summary 37-64, Vol. II, pp. 55–58. Jet Propulsion Laboratory, Pasadena, Calif., Aug. 31, 1970.

Table 1. Synthesizer short-term drift measurements (5 MHz)

Run	Synthesizer	Maximum p-p phase shift in 100-sec interval, deg
3	Dana HP	0.17 0.19
4	Dana Fluke 1	0.16 0.45 (data suspect)
6	Dana HP	0.18 0.25
7	Dana Fluke 2	0.22 0.23

Table 2. Synthesizer long-term drift measurements (5 MHz)

Run	Period, h	Synthesizer	Maximum p-p drift, deg	Maximum drift rate millideg/sec	Stability (parts in 10^{13})
1	45	Dana Fluke 1	3.3 30.6	0.15 1.5	0.82 8.2
2	65	Dana HP	8.0 6.5	0.94 1.8	5.2 1.0
5	40	Dana HP	1.8 8.0	0.23 0.45	1.4 2.5
8	92	Dana Fluke 2	2.9 19.0	0.34 1.8 23.0 (Fluke perturbation)	1.9 10.0 130.0 (Fluke perturbation)

Table 3. Typical synthesizer performance

Synthesizer	Max p-p drift, deg	Max drift rate, millideg/sec	Stability	Max p-p phase shift in 100-sec intervals, deg
Dana 7030	3	0.4	2×10^{13}	0.2
HP 5100A/5110A	8	0.4	2	0.2
Fluke 644A	20	2.0	10	0.2
Fluke 644A		23.0	130 (due to spontaneous perturbation)	

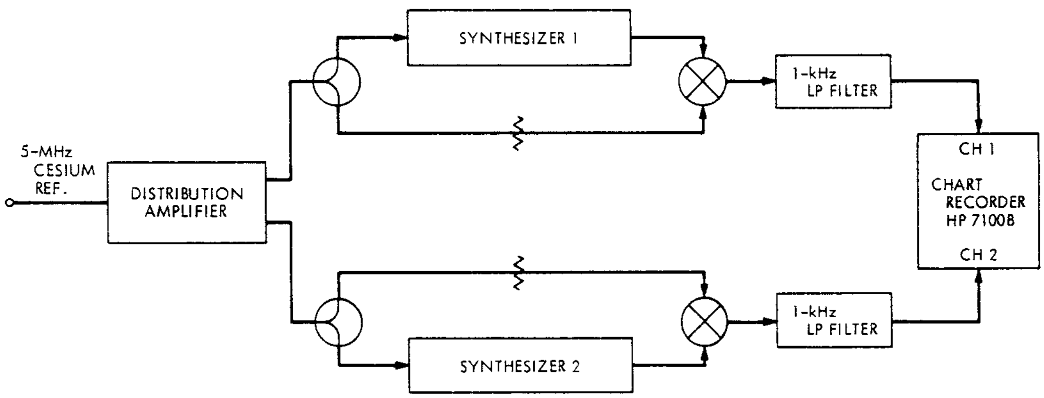

Fig. 1. Synthesizer stability measurement system

Fig. 2. Synthesizer stability test run 8 (long-term)

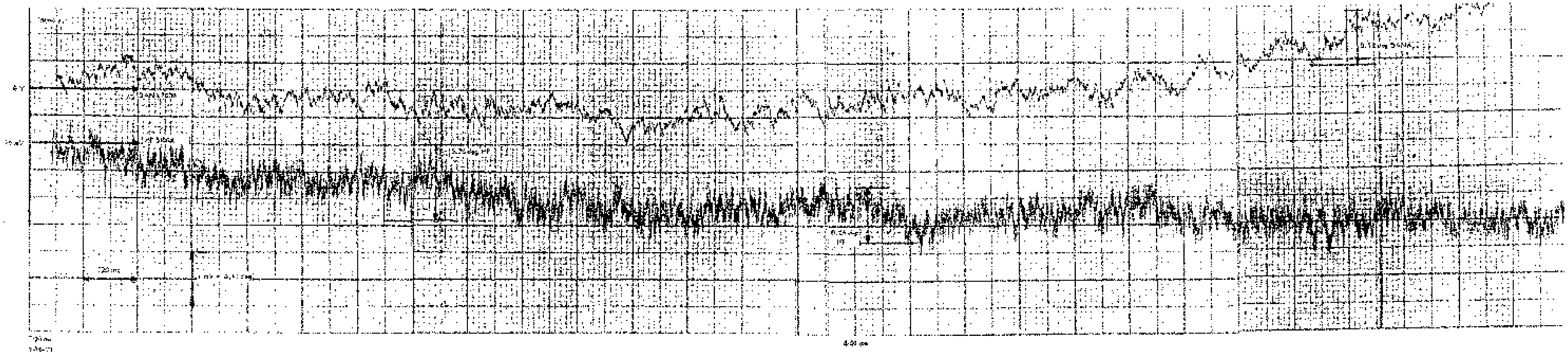

Fig. 5. Synthesizer stability test run a (short-term)