Receiver Stability

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This article reports the results of phase stability investigation of the Dana Digiphase Synthesizer being used in the Block IV Receiver–Exciter Subsystem, with comparative data on the Hewlett-Packard Synthesizer used in the Block III Receiver–Exciter Subsystem. This is the first of a series of articles to verify that the stability of the Block IV Receiver–Exciter is adequate for very long baseline interferometry measurements.

I. Introduction

In the early stages of the Block IV Receiver–Exciter design (Ref. 1), primary consideration was given to developing a receiver with minimum variation in phase and group delays to obtain more accurate doppler and ranging data. To determine which portions of the receiver–exciter contributed the major portions of the phase and group delay variations, a series of tests was conducted on a Block III Receiver–Exciter. These tests indicated that the major contributors to phase and group delay variations are the oscillators, phase modulators, and frequency multipliers. In addition, these tests showed that these variations are primarily a function of changes in ambient temperature. In order to reduce the magnitude of the phase and group delay variations, the following designs are incorporated into the Block IV Receiver–Exciter:

(1) The doppler signal is extracted from the local oscillator at S- or X-band. In this configuration, the receiver phase loop compensates for any phase variation in the local oscillator chain, thus resulting in no phase error appearing in the doppler output due to these variations.

(2) Phase delay variations in the exciter frequency multipliers and transmitter are corrected by using a stable frequency multiplier chain to generate a reference signal and then using the reference signal to control the phase of the transmitter output.

(3) The range phase modulator is enclosed in an oven to minimize group delay variations of this temperature sensitive circuit.

(4) A Dana Digiphase Synthesizer is used in the exciter in order to reduce oscillator phase variations. Phase stability characteristics of this synthesizer are discussed in this article and also in Ref. 2.

With these designs, the Block IV Receiver–Exciter doppler and ranging stabilities have been significantly improved over the Block III design, easily complying with existing navigational requirements.

II. Receiver Stability Investigation

The Block IV Receiver–Exciter design emphasis was on phase and group delay stability for good doppler and ranging data in the closed-loop receiver configuration. With the proposed use of the Block IV Receivers in the open-loop configuration for interferometry measurements, the phase delay stability of the receiver's local oscillators now becomes as important as the phase and group delay stability of the rest of the receiver. The phase delay stability of these local oscillators as well as other portions of the receiver must be investigated to verify that the actual stability of the Block IV Receiver–Exciter is adequate for very long baseline interferometry (VLBI) measurements regardless of the fact that the present specification had been developed for doppler and ranging accuracy requirements. To determine this, an investigation of phase and group delay stability has been initiated. The first item under investigation is the Dana Digiphase Synthesizer being used as the oscillator in the receiver's first local oscillator. The results of this investigation are reported in this article together with similar data on the Hewlett-Packard (HP) Synthesizer used in the Block III Receiver–Exciter for comparison. These data were taken in three separate tests: the Dana Synthesizer, the HP Synthesizer, and a comparison of the two.

A. Test 1—Dana Digiphase Synthesizer (7010-S-241)

The Dana Synthesizer was tested by comparing its 50-MHz reference input against its output which was programmed at 50 MHz (see Fig. 1). The input reference and output were compared by using a Hewlett-Packard Vector Voltmeter 8405A in order to measure the phase variations in the Dana. The test was conducted for a period of 2 hours. The temperature during this 2-hour period varied approximately 1°C. The measured phase drift of the Dana was 0.13 degrees peak-to-peak per degree Celsius and varied directly with the temperature. The measured phase stability of the Dana unit was within the specified limit of ±0.1 degree per degree Celsius.

B. Test 2—Hewlett-Packard Synthesizer (HP5100A)

The Hewlett-Packard unit was also tested for a period of 2 hours in a similar manner (see Fig. 2). The HP unit again showed greater phase delay variations than the Dana Synthesizer as it did in earlier tests when the Dana was selected rather than the HP for the Block IV Receiver–Exciter. The measured phase delay variation was approximately 3.0 degrees of phase per degree Celsius; the phase delay also varied directly with temperature.

C. Test 3—Comparison of Dana and Hewlett-Packard

A third test was conducted by comparing a 45-MHz output of each unit for phase deviation (see Fig. 3). As expected, after a 2-hour test period, the total phase drift was approximately 3.0 degrees of phase per degree Celsius. The phase drift of the Dana Synthesizer is negligible when compared to that of the Hewlett-Packard unit. These data were consistent with previous data on the HP Synthesizer, as seen in Fig. 2.

The stability of the instrumentation, used during these tests, was checked to assure that the measured phase delay drifts were within the synthesizers themselves (see Fig. 4). The maximum peak-to-peak measured phase delay variation of the instrumentation was 0.05 degrees over a 2-hour period and over the same temperature range as in Tests 1, 2, and 3.

III. Conclusion

These synthesizer tests are the first of a series to determine the capability of the Block IV Receiver for VLBI measurements. The total effect of the synthesizer phase delay variations on the data accuracy must take into consideration the multipliers in the local oscillators. Table 1 lists the frequency multiplication factor for each receiver mode in the open-loop configuration and the effect the synthesizer phase delay variations would have on VLBI data due to the multiplication factor. As seen from Table 1, in the open-loop configuration, the Block IV Receiver has less phase delay variation due to synthesizer drift than the Block III by a factor of at least 23.

References

1. Donnelly, H., Shallbetter, A. C., and Weller, R. E., "Block IV Receiver–Exciter Development," in *The Deep Space Network*, Space Programs Summary 37-66, Vol. II, pp. 115–124, Jet Propulsion Laboratory, Pasadena, Calif., Nov. 30, 1970.

2. Wick, M. R., "DSN Programmed Oscillator Development," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. VIII, pp. 111–124, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1972.

Table 1. Synthesizer phase delay variation contribution to data inaccuracy

Receiver (open-loop configuration)	Local oscillator frequency multiplier	Synthesizer phase delay variation/°C	Receiver phase delay variation/°C due to synthesizer
Block III			
S-band	48	3.0	144
X-band	176	3.0	528
Block IV			
S-band	40	0.13	5.2
X-band	170	0.13	22.1

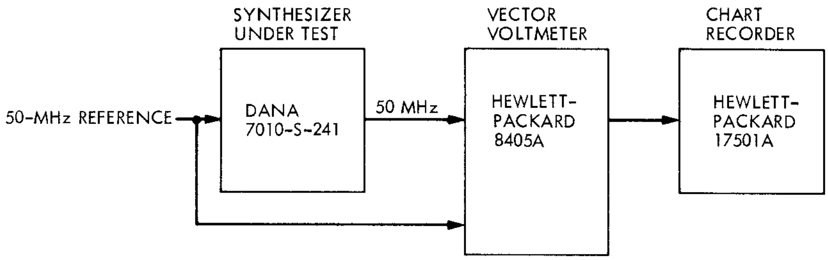

Fig. 1. Phase stability test: Dana Model 7010-S-241

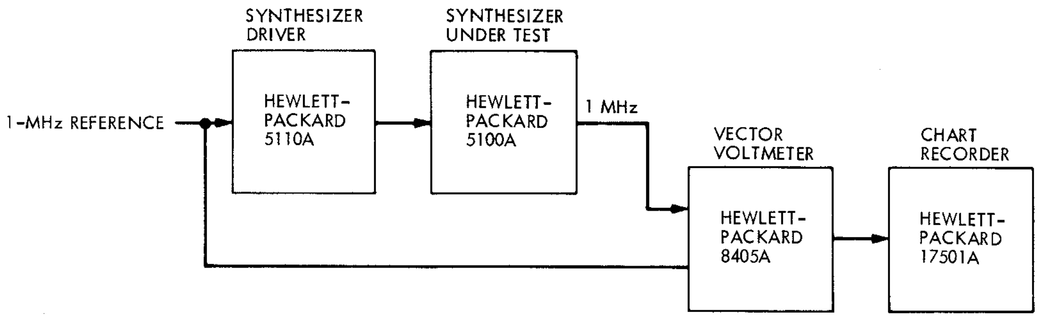

Fig. 2. Phase stability test: HP Model 5100A

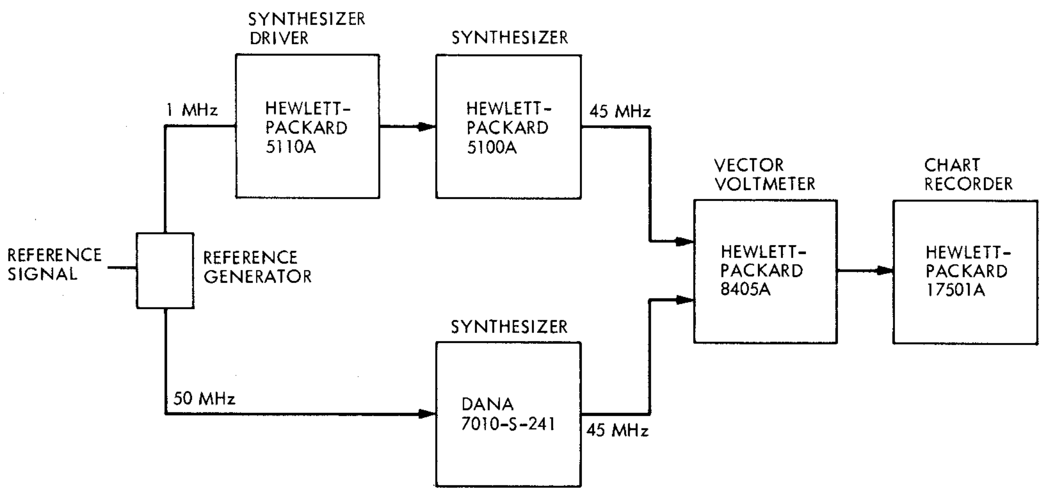

Fig. 3. Phase stability test: Dana vs HP

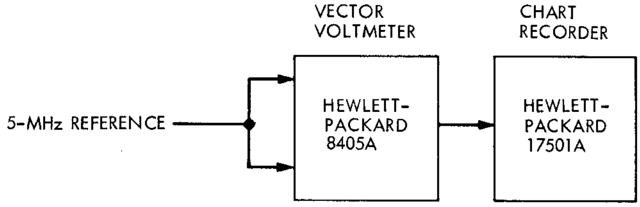

Fig. 4. Phase stability test: Instrumentation