

Multipurpose Exciter With Low Phase Noise

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This article reports results of an effort to develop a lower-cost exciter with high stability, low phase noise, and controllable phase and frequency for use in Deep Space Network and Goldstone Solar System Radar applications. It includes a discussion of the basic concept, test results, plans, and concerns.

I. Introduction

The advanced exciter development effort arose from a desire to use a high-quality commercial synthesizer to produce a new generation of exciters for the Deep Space Network (DSN) and Goldstone Solar System Radar (GSSR) transmitters. The design is based on the fact that multiplying a frequency also multiplies its phase noise, while translating frequency only adds a fixed amount of phase noise. Since a major part of the phase noise of an exciter is produced by the synthesizer, the synthesizer should not be followed by a frequency multiplier. Frequency translation, however, generates image frequencies that must be filtered. When the synthesizer frequency is above 300 MHz, image filtering is practical for all bands up to 35 GHz. Figure 1 is a block diagram of the translation system [1].

II. Preliminary Design

The Hewlett-Packard (HP) 8662A synthesizer has very low added phase noise in the range of 320 to 640 MHz. Two limitations for exciter applications, however, are that frequency resolution is limited to 0.1 Hz and that phase continuity is not guaranteed when changing frequency. Both these problems are addressed by the factory-supplied option C-03 [2]. This option provides an extra input to the HP 8662A for the injection

of a signal between 10 and 20 MHz, which is added to the output frequency. The range of phase-continuous operation is restricted because the HP 8662A must be reprogrammed if the auxiliary frequency changes by more than 2 MHz. When the signal to be added is derived from an HP 3325A function generator, it provides phase-continuous frequency changes over any 2-MHz range with 0.001-Hz resolution. There is, however, increased phase noise. Figure 2 shows measured phase noise of the HP 8662A at 640 MHz by itself and with the ability to adjust the absolute phase of the output with a precision of 0.1 degree.

Different multiplier configurations were evaluated for long-term stability. Figure 3 shows three such configurations, and Fig. 4 is the resulting Allan variance at X-band of each. In these figures, (a) uses a step recovery diode (SRD) harmonic generator driven by an auxiliary 640-MHz output of the HP 8662A; (b) is an SRD harmonic generator driven by 400 MHz derived from the frequency and timing subsystem (FTS); and (c) is a single-frequency multiplier driven by 100 MHz from the FTS. These data indicate that the single-frequency multiplier is preferable to the SRD harmonic generator.

Based on these data, the prototype X-band exciter, shown in Fig. 5, was assembled for further evaluation.

III. Test Data

Figure 6 presents measured phase noise of three X-band exciters. The GSSR exciter was measured at Goldstone by the authors, the current DSN X-band exciter data were published in [5], and the prototype exciter shown in Fig. 5 was measured by the JPL Frequency Standards Test Lab (FSTL).

Figure 7 is a comparison of the Allan variance of the current DSN X-band exciter and the prototype exciter. Data for the DSN system come from [5], and the advanced exciter was measured by the FSTL using the system shown in Fig. 8. The measurement technique is described in [4].

The measured data indicate that the proposed advanced exciter yields a substantial improvement in phase noise and is comparable to the more complex DSN exciter in long-term stability (Allan variance).

IV. Configuration

The first operational test of the prototype advanced exciter will be for the GSSR X-band transmitter. Figure 9 is a block diagram of the intended configuration, with heavy lines indicating new elements and dotted lines for deleted elements. In this test configuration, the advanced exciter can also function as the first local oscillator for the receiver since the transmitter and receiver never operate at the same time. Additional effort will be required on the predicted Doppler interface, however, before this part of the test can be completed.

A rough analytical model of the noise sources in the exciter has been developed. The reason the results of the SRD harmonic generator were so disappointing needs to be learned. The multiplier and filters required to measure phase noise and Allan variance at S-band have been ordered. Tests at Ka-band are also possible.

V. Discussion and Conclusions

The present work has shown the feasibility of producing an advanced exciter using commercial equipment. The exciter will have a number of desirable features, including the following:

- (1) Low phase noise;
- (2) High long-term stability;
- (3) Phase-continuous frequency adjustment with 2-MHz range and 0.001-Hz resolution at any frequency;
- (4) Absolute phase control with 0.1-degree resolution at any frequency;
- (5) Computer-driven frequency and phase control, so that a phase versus time record can be kept and used for digital Doppler extraction;
- (6) Ability to function as the first local oscillator for the receive channel. In this use it can track (remove) predicted Doppler. This function is necessary for GSSR use, and can improve performance in DSN applications by allowing lower receiver bandwidth.

VI. Concerns

Absolute phase accuracy of the advanced exciter still needs to be demonstrated. One factor that affects it is any uncertainty in the time in which frequency changes are executed. Although this is a small effect, it may accumulate to an error in absolute phase. Another factor is that the HP 8662A synthesizer has a reputation for being susceptible to "popcorn noise" or occasional phase steps. This has not been observed in the prototype exciter, but testing of additional units is required to determine if this will be a problem in operational systems.

Acknowledgments

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References

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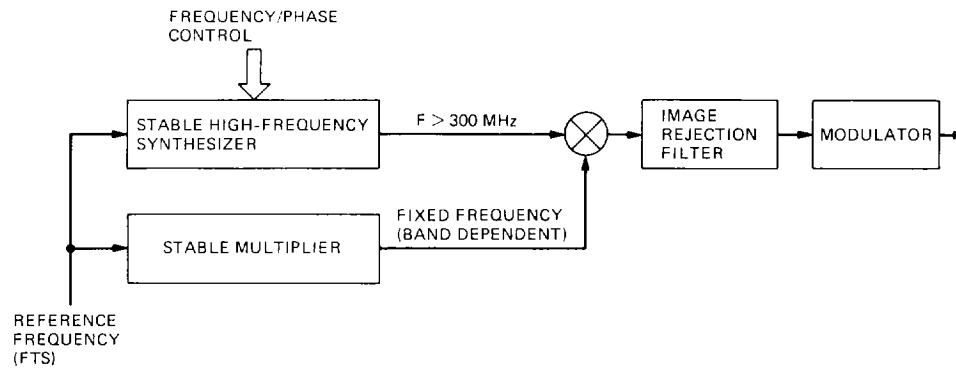


Fig. 1. Frequency translation system.

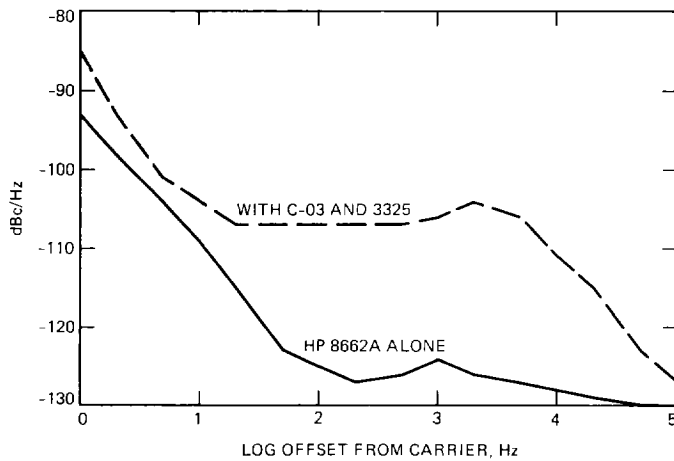


Fig. 2. Added noise from option C-03, single-sideband (SSB) phase noise at 640 MHz.

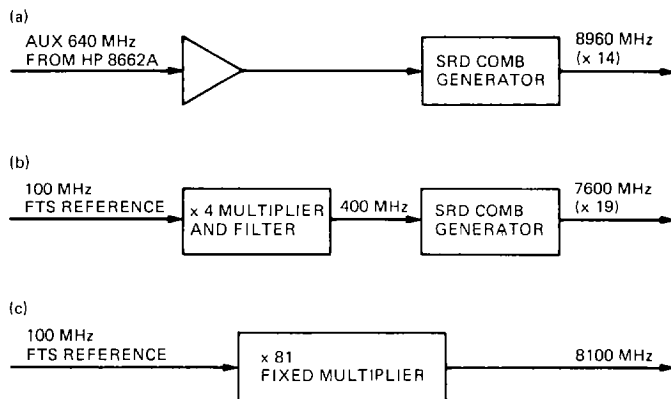


Fig. 3. Multiplier configurations: (a) SRD driven by 640-MHz auxiliary output of HP 8662A; (b) SRD driven by 400 MHz from FTS reference; (c) x81 fixed multiplier.

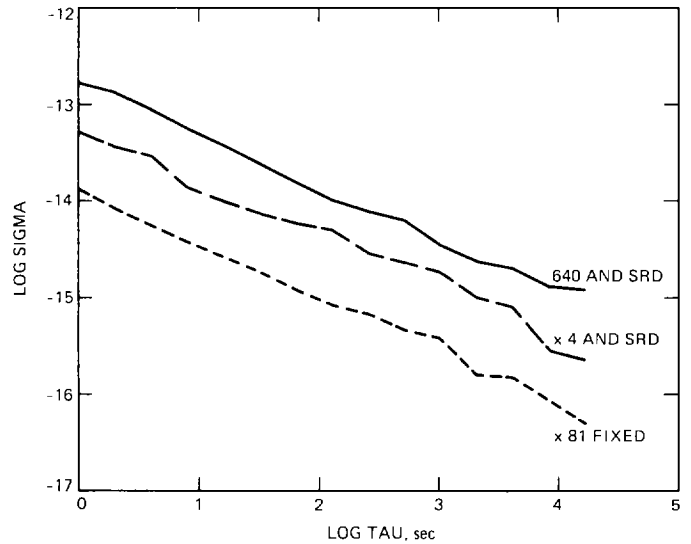


Fig. 4. Allan variance versus multiplier type, measured at X-band.

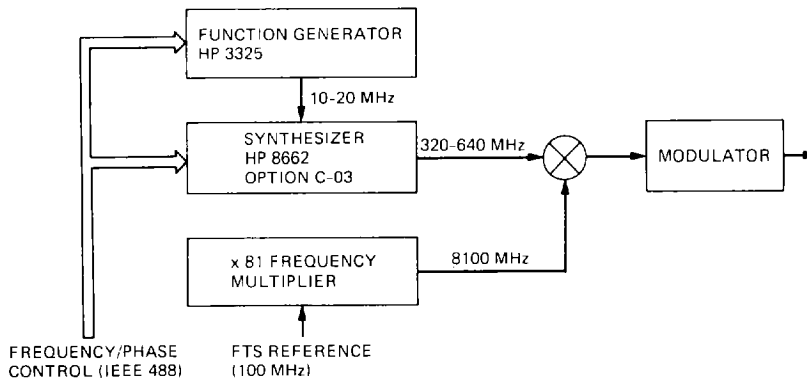


Fig. 5. Prototype X-band exciter.

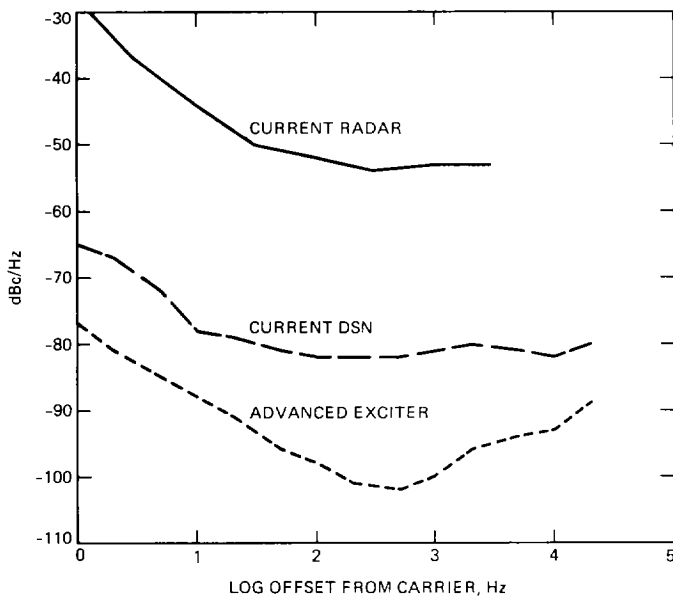


Fig. 6. SSB phase noise, measured at X-band.

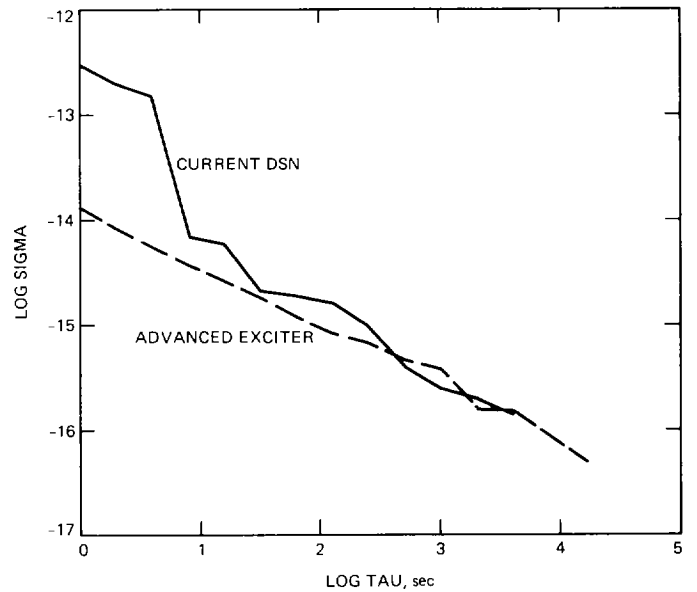


Fig. 7. Allan variance, measured at X-band.

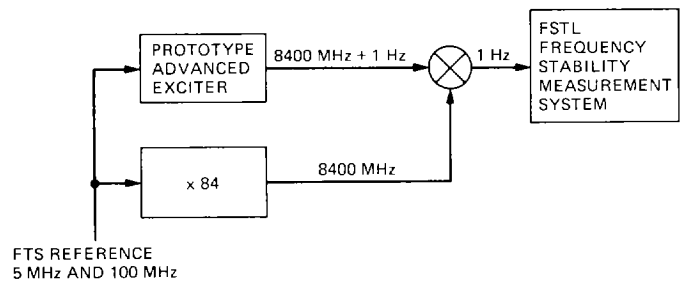


Fig. 8. Allan variance test setup.

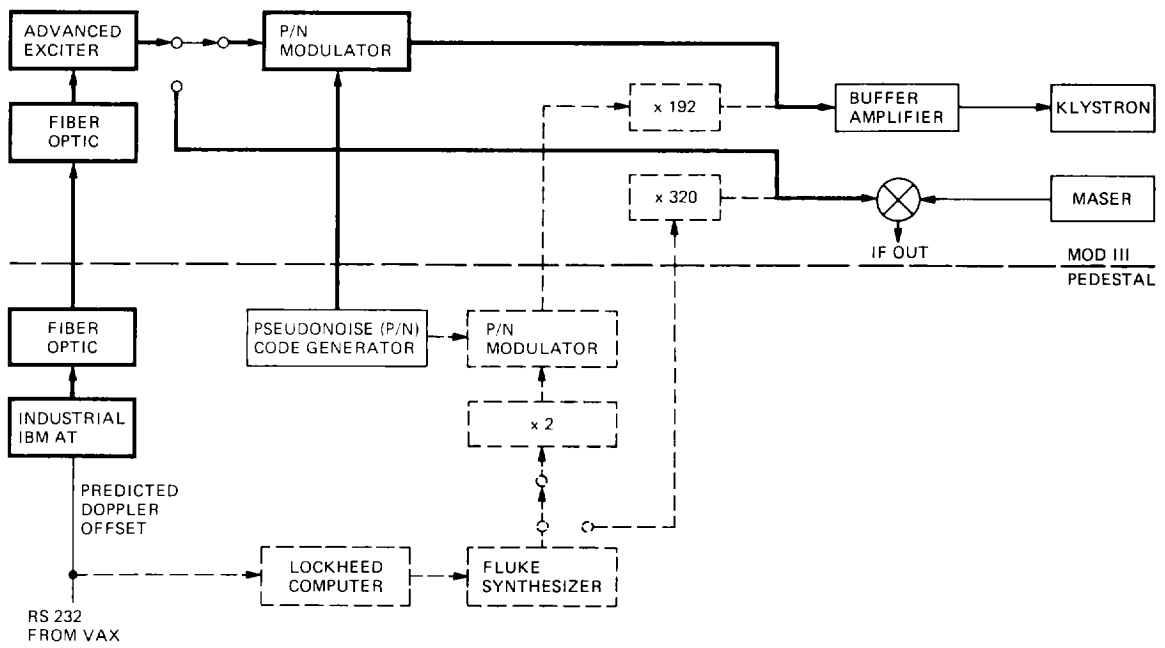


Fig. 9. Block diagram exciter installation, GSSR.