X-Band Uplink Ground Systems Development

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The development of the X-band exciter and Doppler extractor equipment for the X-band uplink has been completed. Stability measurements have been made on the exciter and Doppler reference signals and the results are presented.

I. Introduction

The development of a stable X-band RF subsystem was prompted by requirements for increased accuracies of spacecraft navigation and charged particle calibration. The design goal was to develop an X-band uplink with a fractional frequency ($\Delta f/f$) stability of 5×10^{-15} over a 1000-s integration period.

To accomplish this goal, a stable X-band exciter and Doppler extractor system was developed (Ref. 1) that would provide the required stability.

The fabrication of the prototype exciter and Doppler extractor has been completed and tests were performed at JPL to verify the stabilities of the exciter and the S- and X-band Doppler reference signals. The results of the tests are presented.

II. Exciter Functions

A. Exciter Stability

Exciter stability measurements were made at JPL using the Maser Test Facility. A simplified diagram of the test set-up is shown in Fig. 1. Briefly, the exciter signal was set to 7.2 GHz + 1 Hz and phase compared with a stable 7.2-GHz signal generated from a hydrogen maser. The 1-Hz difference signal, at the phase comparator output, was fed to the Allan variance computer.

In addition, maser-derived 10-MHz and 100-MHz references were supplied to the exciter synthesizer and the exciter, respectively.

The result of the exciter stability measurement is shown in Fig 2. The stability at the 1000-s integration period is seen to be about 2.5×10^{-15}, which agrees closely with prior computations (Ref. 1 and Fig. 3).

B. Doppler Reference Signals

The exciter also generates coherent X- and S-band Doppler reference signals. The frequency of these signals, relative to the exciter frequency, fx, are:

$$\text{S-band Doppler} = 240/749\, fx$$

$$\text{X-band Doppler} = 880/749\, fx$$

To generate the Doppler references, a $fx/80$ signal (Ref. 1 and Fig. 4) is multiplied to $131/749\, fx$ and then summed with fx to yield the X-band Doppler. In a second path, the $fx/80$ signal is multiplied to $509/749\, fx$ and subtracted from the fx signal to yield the $240/749\, fx$ Doppler reference.

The stability of both Doppler references were also measured and the results are shown in Figs. 3 and 4.

III. Doppler Extractor

Included with X-band exciter hardware for DSS 13 is a new Doppler extractor to permit Doppler extraction using the receiver's second local oscillator (LO). The extraction scheme is shown in Fig. 5. As shown, the Doppler first IF is generated by mixing the stable 8.1-GHz first LO frequency with the Doppler reference signal generated within the exciter. The Doppler first IF does not contain Doppler information, but after it is mixed with the receiver's second LO, the resulting 1050-MHz IF signal contains Doppler information. This signal is subsequently down-converted to 50 MHz and then again down-converted to 1 MHz and 5 MHz biased Doppler signals.

This method of Doppler extraction reduces receiver phase instabilities by a large factor and was considered a prerequisite for achieving the 5×10^{-15} stability goal.

IV. Receiver Configuration

To utilize the new Doppler extractors at DSS 13, the present Block II receivers will be modified as shown in Fig. 6. The X- and S-band receivers are identical in configuration and only one is shown for simplicity.

Functionally, the X-band receiver is similar to the X-band Doppler extractor to the extent that from the X-band inputs to the 50-MHz outputs, the IF signals in each are identical. In the same respect, the S-band receiver is similar to the S-band Doppler extractor.

The receiver 50-MHz IF is fed into the standard Block III receiver input. The Block III LO was modified to allow locking to the 350-MHz IF.

V. Conclusions

The initial tests made on the X-band exciter and Doppler reference signals have verified the accuracy of the original stability estimate of 2.5×10^{-15} for 1000-second integration periods.

Receiver and Doppler hardware instabilities will degrade the overall system performance. Estimates have been made that a total system stability of 5×10^{-15} will be attained, as measured at the biased Doppler output. Future testing will be performed at DSS 13 to evaluate the complete system and verify the estimates.

All RF hardware has been delivered to DSS 13 and is awaiting final interface cabling to complete the X-band uplink installation.

References

1. Hartop, R., Johns, C., and Kolbly, R., "X-band Uplink Ground Systems Development," *The Deep Space Progress Report 42-56, January and February 1980*, pp. 48-58. Jet Propulsion Laboratory, Pasadena, California.

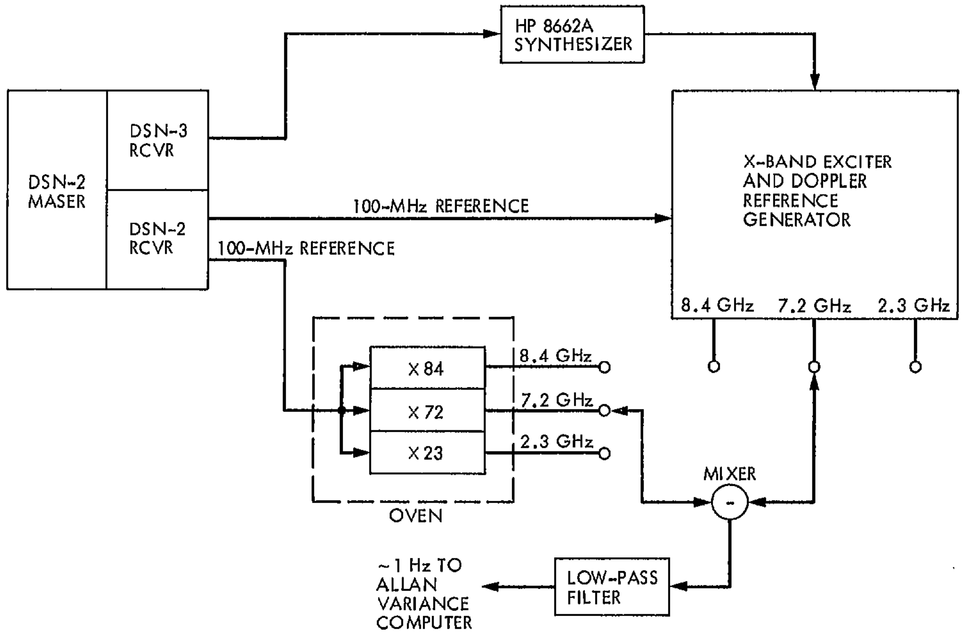

Fig. 1. Simplified diagram of stability test setup

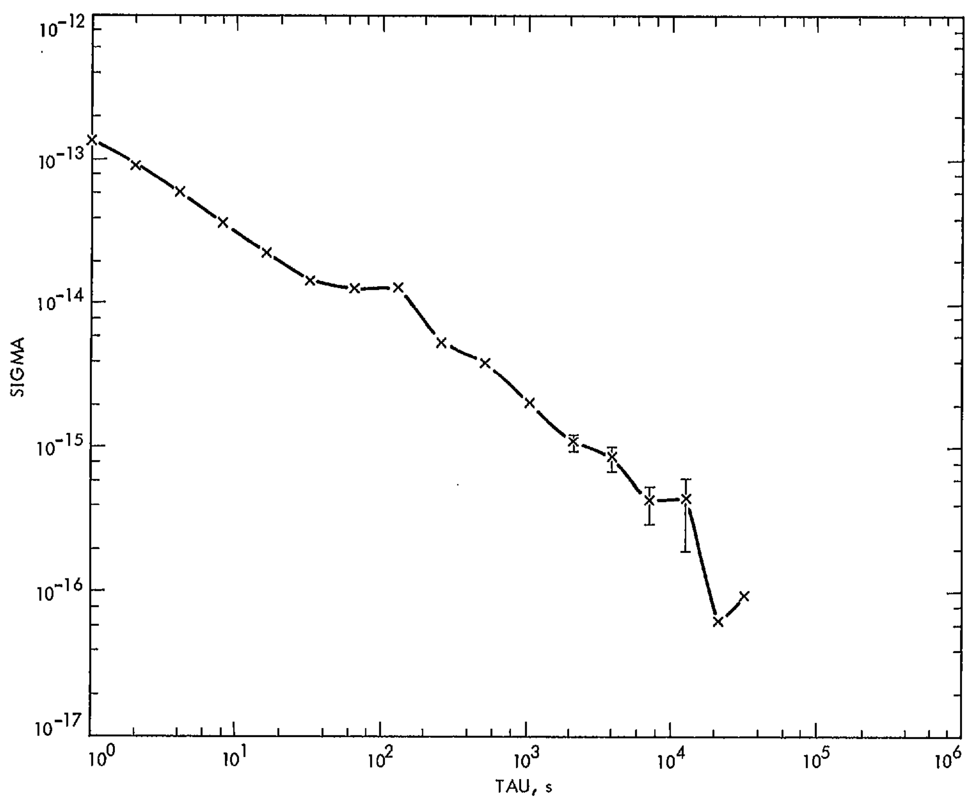

Fig. 2. 7.2-GHz exciter output stability

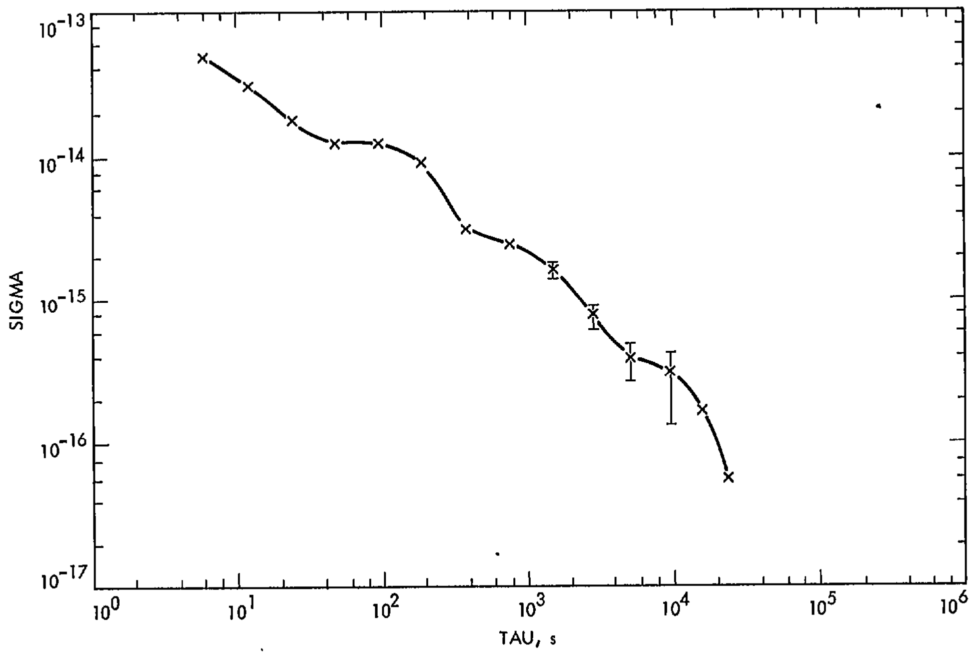

Fig. 3. 8.4-GHz Doppler reference stability

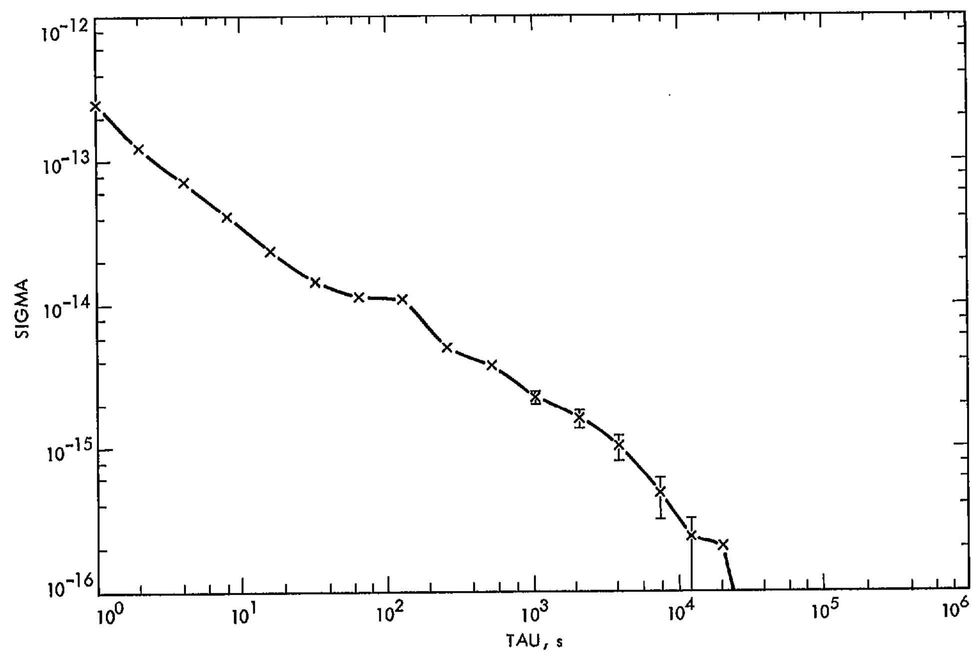

Fig. 4. 2.3-GHz Doppler reference stability

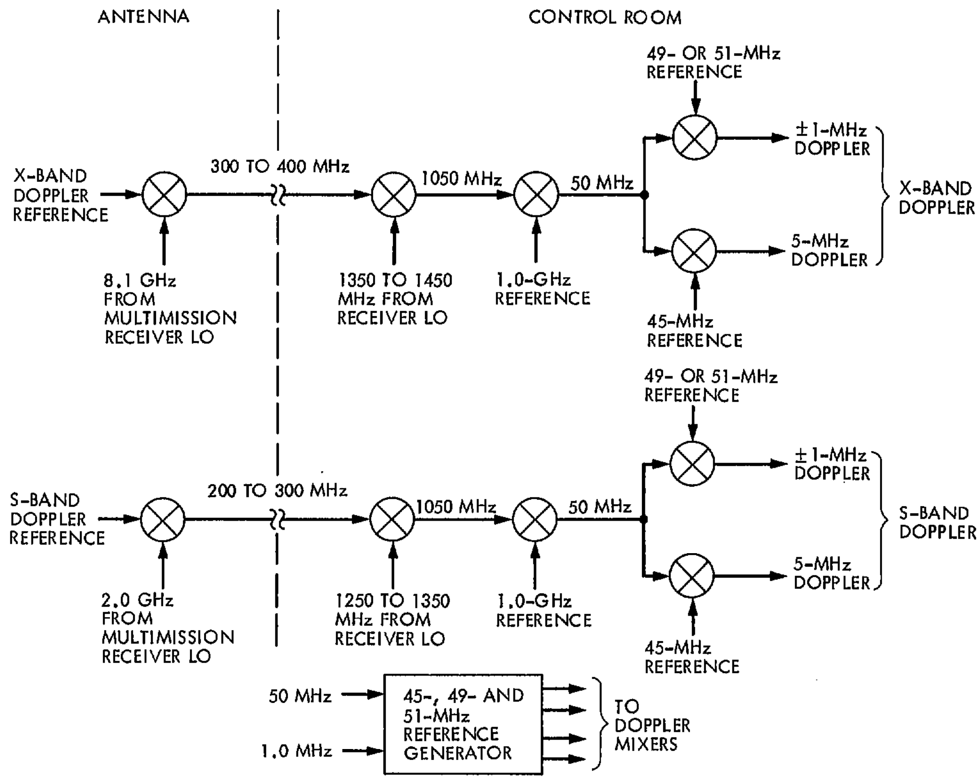

Fig. 5. X- and S-band Doppler extractor scheme

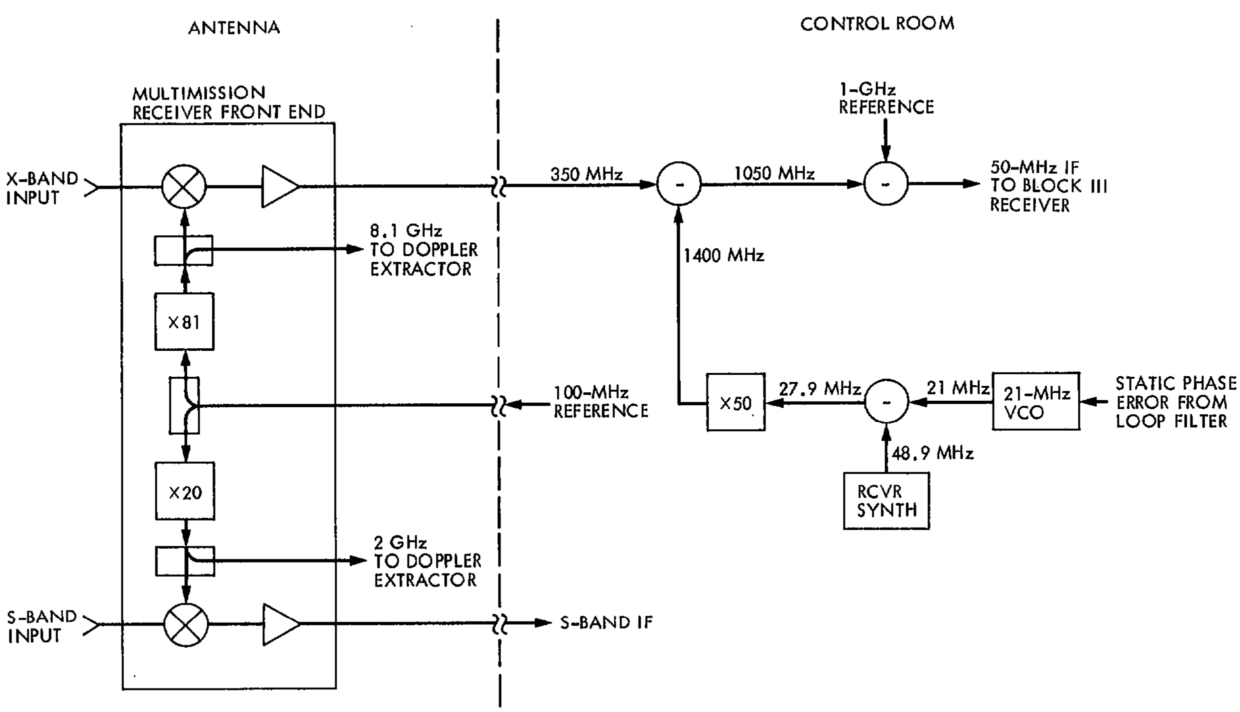

Fig. 6. Simplified diagram of the X-band receiver