S/X Experiment: A New Configuration for Ground System Range Calibrations With the Zero Delay Device

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A new configuration for ground system range calibrations with the zero delay device (ZDD) was recently implemented at DSS 14 for the S/X experiment. In this new configuration, the original ZDD horns and associated air paths are eliminated. The uplink test signal is now coupled out of the transmitter waveguide path and brought directly to the ZDD by calibrated cables of known delays. The downlink signals generated by the ZDD are injected directly into the masers via calibrated cables and waveguide couplers. Preliminary tests on the new system indicate that, in the absence of the air path, the ground system range change as a function of antenna elevation angle is typically less than 3 ns at S-band and X-band.

I. Introduction

With the exception of DSS 14, all stations of the Deep Space Network use the conventional zero delay ranging configuration, in which the zero delay device (ZDD) is mounted on the dish surface. A zenith range measurement to a dish-mounted ZDD and a simple Z-height correction (Ref. 1) should provide all of the needed ground station information for determining the true range to the spacecraft. However, as was pointed out in a separate article (Ref. 2) in this volume, results of tests showed that large changes in range occurred as a function of antenna elevation angle when a ZDD was placed on the 64-m antenna dish surface. Since the changes could be due to a multipath phenomenon, one cannot assume that a zenith measured value is the correct value. It was further reported in Ref. 2 that a satisfactory location in the Mod-3 area was found for the ZDD at S-band, but the performance at X-band was unsatisfactory.

Because of the described problems with the conventional ZDD configuration, it was proposed by G. S. Levy that, for the S/X experiment, the ZDD horns and associated air paths be eliminated and replaced by semirigid cables. This article describes the new configuration and presents results of some preliminary tests.

II. New Configuration

A block diagram of the current ZDD calibration system at DSS 14 may be seen in Fig. 1. This new configuration was installed on the 64-m antenna system at DSS 14 on January 12, 1974.[1] In this new configuration, the uplink 2113-MHz signal is now sampled from a directional coupler in the waveguide transmit line and carried directly to the ZDD by coaxial cables of known delay. The downlink signals of 2295 and 8415 MHz generated by the ZDD are carried by calibrated cables and injected directly into the respective S- and X-band masers via directional couplers. Figure 2 shows the block diagram of the ZDD assembly as presently modified for this new configuration. The original block diagram for the ZDD was previously shown in Refs. 3 and 4.

The main disadvantage of the new method is that, by elimination of the air path, one is not able to use the ZDD to detect problems which might occur in the microwave optics subsystem. With the new ZDD configuration, one is restricted to testing only the portion of the ground

[1]A previous similar configuration was installed on December 20, 1973, but is not described in this article. This previous system could only be used with the 20-kW transmitter.

system that includes the transmitter, masers, Block 4 receivers, and associated waveguide and cable paths. A second disadvantage of the new method is that there is no longer just a simple Z-height correction that must be added to the measured ZDD range value. As described in an article elsewhere in this volume (Ref. 5), the new Z-correction now requires knowledge of range delays in all portions of the uplink and downlink signal paths that are not mutually common to the "Range-on-ZDD" path and "Range-on-Spacecraft" path as defined up to the antenna bench mark. Knowledge of these delays requires (1) group delay calibrations of cables to and from the ZDD, (2) group delay calibrations of portions of the transmit/receive waveguide paths, and (3) calculations of air path delays via the microwave optics path. A tabulation of the delays as calibrated with a phase-locked network analyzer system is presented in Table 1 for the DSS 14 ground system depicted in Fig. 1. It should be pointed out that any new equipment installation in the paths described in Table 1 will invalidate the calibrations.

The advantage of the new method is that the range and phase calibrations will be more stable and repeatable. As will be shown later, the range delay variation with antenna tipping is very small. A second advantage is that a theoretically calculated air path delay should be more accurate than a ZDD measured value which is apparently corrupted by multipath effects. A theoretical analysis can account for the total integrated effects of a far-field illuminator and therefore more closely represent the actual spacecraft range configuration. The elevation angle dependence of range to quadripod blockage, reflector surface distortions and sagging, reflections from antenna-mounted structures, and subreflector defocussing can be studied analytically.

III. Test Results

Figures 3 and 4 show preliminary results of range tests on the new ZDD configuration using the 100- and 20-kW transmitters, respectively. It can be seen that the maximum range change with elevation angle was about 3 ns for S-band and X-band. Additional tests showed that insignificant changes of range occurred as functions of azimuth angles for either the S- or X-band system. These preliminary test results indicate that the group delays of the transmitters, masers, Block 4 receivers, and associated cabling are nearly insensitive to antenna motion.

The ZDD was also used to test the doppler phase stability of the S- and X-band systems as functions of antenna tipping. The peak phase changes due to doppler phase jitter and antenna tipping were typically found to be less than ±30 deg for S-band and X-band. Some of the phase changes that were observed could be attributed to the quantization error of the S/X doppler resolvers. The peak error due to the resolvers is about ±18 deg for a 5-MHz biased doppler. It should be pointed out again that the measured values do not include possible changes in the air path.

IV. Conclusions

The new ZDD configuration using cable paths rather than the air paths has been found to be virtually insensitive to antenna motion. This new configuration therefore appears to be superior to the original system in terms of repeatability. Since the new configuration does not include the air path, the effects of antenna sag on range and phase stability must now be determined theoretically.

At present the ZDD range values are being taken with the antenna at zenith during the precalibration and postcalibration periods of the Mariner 10 spacecraft tracking passes. Over a period of about 30 days, the differential S/X ZDD range appears to be stable to within 10 ns. The long-term absolute group delay instabilities are about two times greater. An attempt is being made to analyze the changes and correlate them with ambient temperature, maser gain, and Block 4 equipment modifications.

References

1. *TRK-2-8 Module of DSN System Requirements Detailed Interface Design Document 820-13, Rev. A*, Jet Propulsion Laboratory, July 1, 1973 (JPL internal document).

2. Stelzried, C. T., Otoshi, T. Y., and Batelaan, P. D., "S/X Band Experiment: Zero Delay Device Location," in *The Deep Space Network Progress Report*, Technical Report 42-20, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1974 (this issue).

3. Otoshi, T. Y., and Batelaan, P. D., "S/X Band Experiment: Zero Delay Device," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. XIV, pp. 73–80, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1973.

4. Otoshi, T. Y., and Batelaan, P. D., "S/X Band Experiment: Preliminary Tests of the Zero Delay Device," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. XVII, pp. 68–77, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1973.

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Table 1. Summary of group delay measurements pertinent to DSS 14 Z-corrections for the new ZDD configuration implemented on January 12, 1974

Input port (Figs. 1 and 2)	Output port (Figs. 1 and 2)	Measured group delay, ns
2′	A	42.35 $\pm$0.09 (1σ)
A	B	14.11 $\pm$0.76 (1σ)
B	4	87.38 $\pm$0.12 (1σ)
A	C	9.49 $\pm$0.80 (1σ)
C	7	70.63 $\pm$0.10 (1σ)
2′	3	32.77 $\pm$0.08 (1σ)
3	4	37.57 $\pm$0.12 (1σ)
6	7	0.91 $\pm$0.03 (1σ)

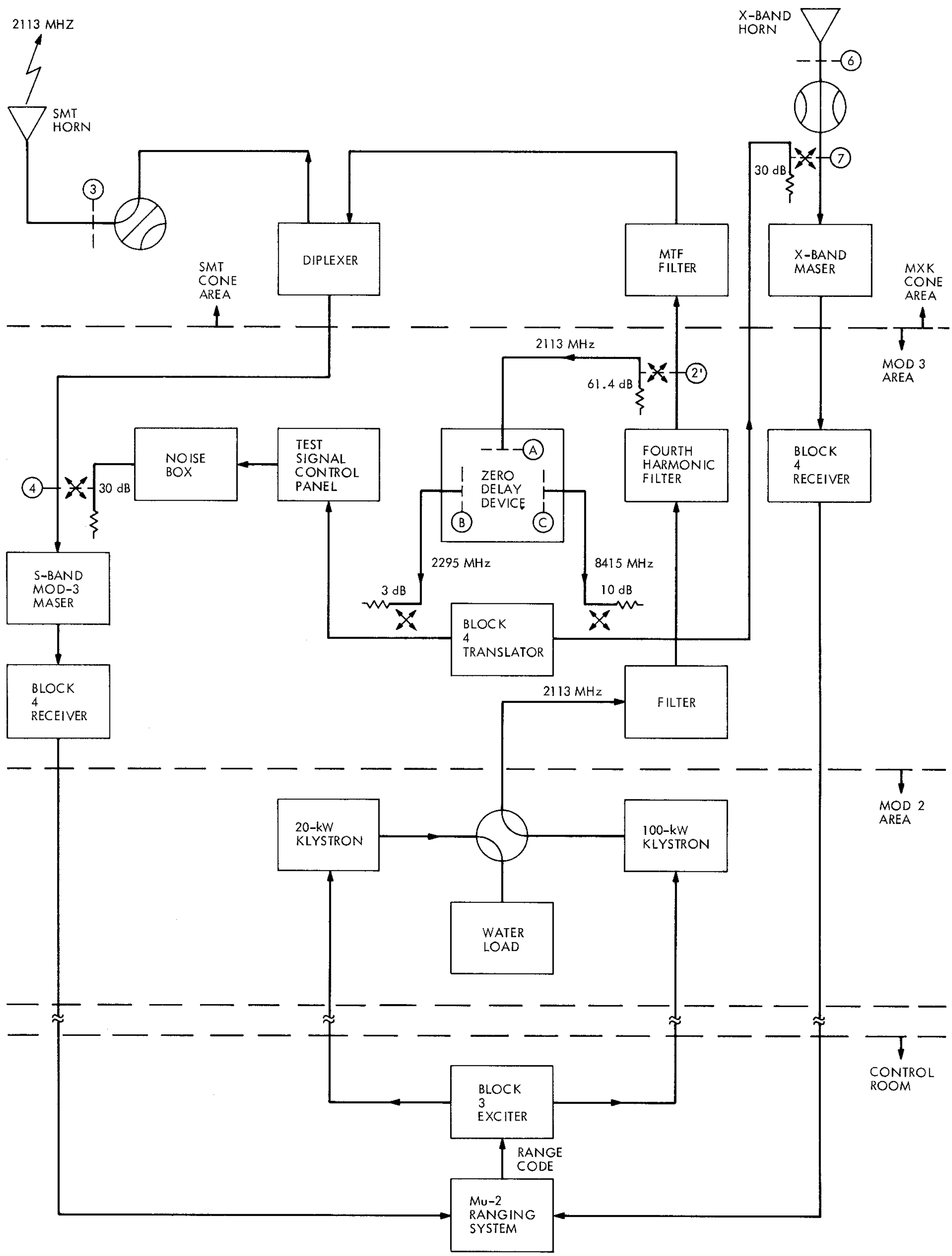

Fig. 1. Block diagram of the new configuration at DSS 14 for ground system range calibrations

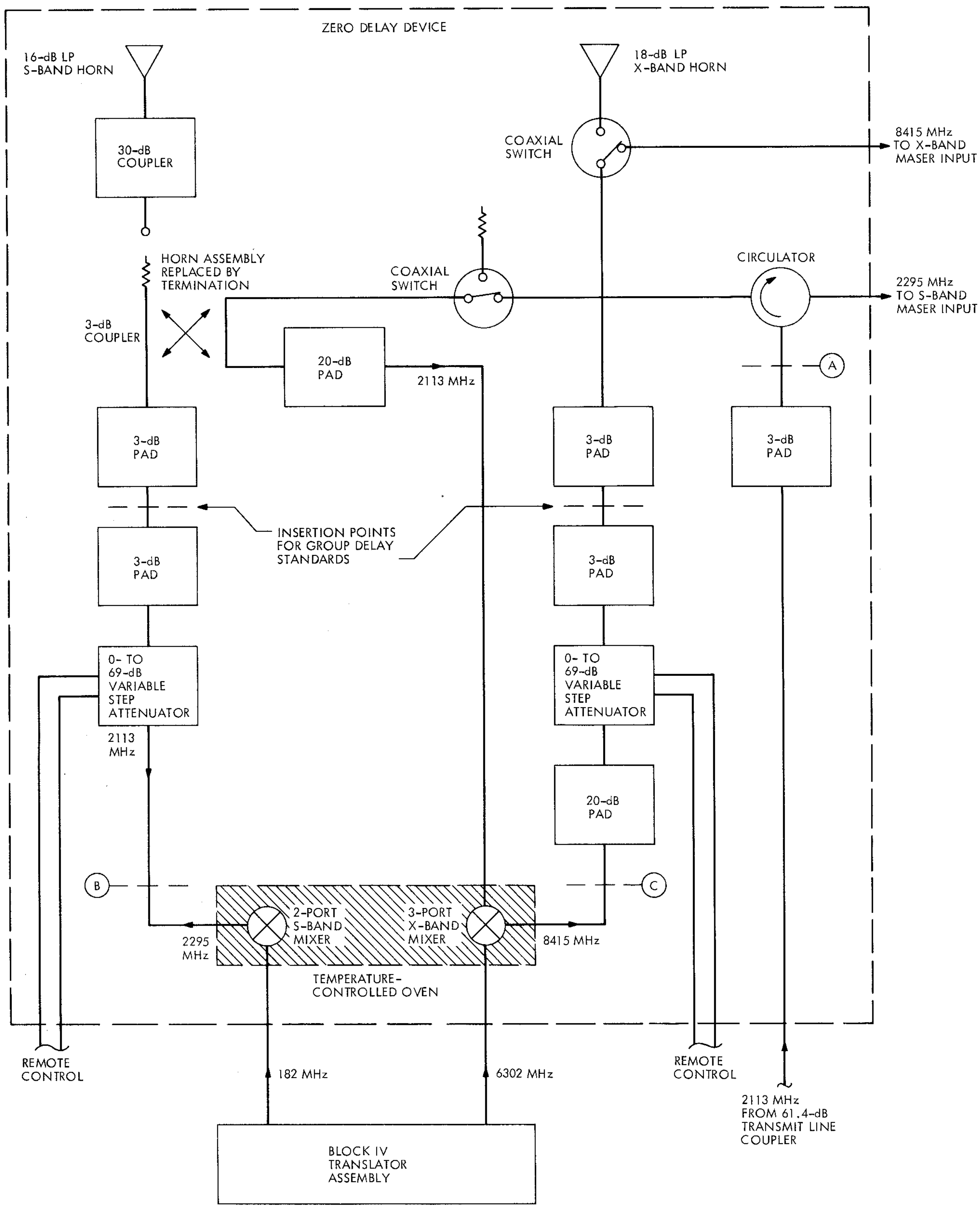

Fig. 2. Block diagram of the current zero delay device assembly at DSS 14

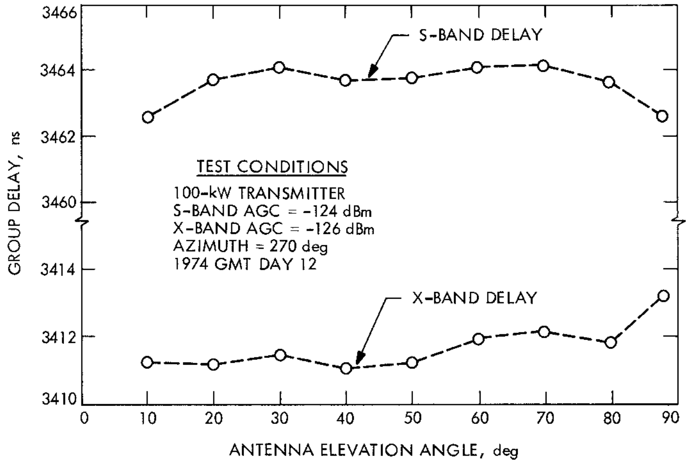

Fig. 3. Range delay as a function of elevation angle using the new ZDD configuration and the 100-kW transmitter

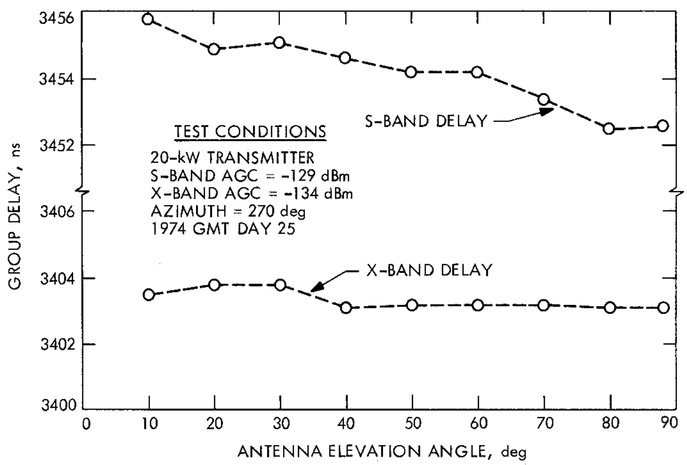

Fig. 4. Range delay as a function of elevation angle using the new ZDD configuration and the 20-kW transmitter