S/X Experiment: Preliminary Tests of the Zero Delay Device

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Preliminary testing of the zero delay device for the S/X experiment was performed at the Telecommunications Development Laboratory. The test setup consisted of a Block IV exciter, the zero delay device under test, a Block III receiver for S-band reception, a Block IV receiver for X-band reception, and a Mini-Mu ranging machine. Group delay through the system was measured as a function of received signal level and zero delay device temperature. The test results are presented and discussed.

I. Introduction

Fabrication of a zero delay device (ZDD), developed for the S/X experiment (Ref. 1), has recently been completed. This device will be installed on the side of the Mod-III section of the 64-m-diam antenna at DSS 14. The ZDD will simulate a spacecraft radio system mounted on the ground antenna itself. It is used for routine tracking precalibrations and will enable group delay and phase stability of the ground radio system to be calibrated as functions of antenna pointing coordinates and ambient temperatures. As was described in a previous article (Ref. 2), the ZDD in the operational configuration at DSS 14 will be used with a Block IV exciter, Block IV S-band receiver, Block IV X-band receiver, and a Mu-2 ranging system. Additional discussions on the principle of operation and detailed block diagrams of the ZDD may be found in Ref. 2.

II. Test Setup

The Block IV exciter/receiver systems and the Mu-2 ranging system are scheduled for installation at DSS 14 in October 1973. Owing to the unavailability of these systems, preliminary checkout of the ZDD assembly was attempted in the laboratory. The use of a Hewlett-Packard 5360A computing counter and other group delay measurement schemes was found to be only partially satisfactory.

It was suggested by L. Brunn of the Spacecraft Telecommunications Systems Section that preliminary ZDD tests be done at the Telecommunications Development Laboratory (TDL). The test equipment and setup at TDL were found to be ideally suited for testing the ZDD assembly. In addition to a Block III receiver for S-band testing, TDL was also equipped with a temperature-controlled test chamber, RF screen room, Mini-Mu ranging machine, and an SDS 920 computer for both phase and group delay data processing. An engineering model Block IV exciter/receiver for X-band testing was made available by the R.F. Systems Development Section.

Figure 1 shows the ZDD placed in the TDL temperature-controlled test chamber. For these temperature tests, phase-stable cables (Flexco F182) were used for all critical RF transmission lines leading into and out of the temperature-controlled environment. A block diagram of the test setup is shown in Fig. 2. Some modifications made to the original ZDD block diagram (Ref. 2) to facilitate testing at TDL were (1) substitution of phase-stable cables for the S- and X-band horns, (2) removal of an S-band 45-dB pad, (3) substitution of a 2113-MHz bandpass filter by a 6-dB pad, and (4) substitution of a 40-dB X-band pad by a 3-dB pad. The substituted pads were chosen to make the received S/X signal levels be approximately the same as anticipated when the ZDD is used on the 64-m-diam antenna with the 400-kW transmitter turned on.

Tests were made by sequentially switching between the S-band Block III receiver and the X-band Block IV receiver. The following operating conditions existed for the calibrations at TDL:

S-band Block III receiver
  Noise figure = 6.1 dB
  RF bandwidth = 12 Hz
  Threshold = −158 dBm

X-band Block IV receiver
  Noise figure = 14 dB
  RF bandwidth = 3 Hz
  Threshold = −155 dBm

Uplink ranging modulation index = 69.2 deg

ZDD power levels: refer to Fig. 2

ZDD mixer oven temperature = 51.9°C

Group delay and phase data were obtained as functions of signal level and the physical temperature of the ZDD assembly. Signal levels were varied by means of the S- and X-band step attenuators on the ZDD assembly. The test chamber temperatures selected for the ZDD tests were 4, 21, and 34°C. The actual temperature extremes in the Mod III section, where the ZDD assembly will be installed, are expected to be well within the temperature range of 0 to 34°C.

III. Test Results and Discussion

Group delay ranging data and phase data were processed by means of special TDL computer programs written for the SDS 920 computer. Output data from the computer was provided every 20 or 30 seconds. However, these integration periods could be changed at the option of the operator. These output data were then averaged manually to obtain an overall mean and standard error applicable to the total integration time at a particular signal level setting or temperature. These mean values of group delay with standard error limits are shown plotted as functions of received signal levels and temperature for S- and X-band frequencies in Figs. 3 to 10.

It is of interest to note in Fig. 3 that at 21°C ambient temperature, the mean value for the S-band group delay changed about 1.6 ns when signal levels were varied over a 40-dB dynamic range. Figure 7 shows that the X-band group delay at 21°C changed about 4 ns when signal levels were varied over a 30-dB range. Similar observations of group delay changes at other temperatures are summarized in Table 1 for convenience of further study. The overall or worst case group delay change as functions of both temperature and signal level was found to be about 5 ns for S-band and 7 ns for X-band.

Table 2 is a summary of group delay repeatability tests at a particular strong signal level setting. The elapsed time between settings was 1 hour or more. The worst change or drift observed at 21°C was 0.77 ns for S-band and 1.56 ns for X-band.

The causes of the group delay changes at the stronger signal levels are not clearly understood at the present time. The changes should not be attributable to the ZDD attenuators because group delay changes of the individual attenuators are less than 0.05 ns over a 69-dB range and 4.4 to 37.8°C temperature range (Ref. 3). Repeatability of the ZDD attenuators was typically better than ±0.02 ns. Some of the group delay changes might be attributed to the ranging system itself. Changes of about ±2 ns have been previously observed on TDL ranging tests of spacecraft radio equipment (Ref. 4).

The data presented in this article should be considered to be preliminary and not necessarily applicable to the final installed configuration at DSS 14. Phase data which were also obtained on the ZDD assembly at TDL are currently being analyzed. The phase test results will be reported in a subsequent article.

Acknowledgments

The ZDD assembly was fabricated and assembled by R. B. Lyon of the Communications Elements Research Section. Jim Weese of the Spacecraft Telecommunications Systems Section and Boyd Madsen of The Boeing Company assisted with the TDL tests. The engineering model Block IV receiver was provided by H. Donnelly, C. Johns, and R. Weller of the R.F. Systems Development Section.

References

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2. 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.
3. Otoshi, T. Y., "S/X Band Experiment: Zero Delay Device Step Attenuator Evaluation," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. XV, pp. 84–87, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1973.
4. Brunn, L., private communication, June 1973.

Table 1. Summary of peak group delay changes observed as functions of signal level and temperature

Temperature, °C	Maximum, ns	Minimum, ns	Difference, ns
S-band mean values for signal levels 18 to 58 dB above threshold			
21.0	232.26	230.69	1.57
4.4	231.35	229.23	2.12
34.0	232.29	230.69	1.60
Postcalibration, 21.0	231.07	227.37	3.70
34°C for max; 21°C postcalibration for min	232.29	227.37	4.92
X-band mean values for signal levels 5 to 35 dB above threshold			
21.0	279.08	275.06	4.02
4.4	274.40	272.01	2.39
34.0	276.24	272.89	3.35
Postcalibration, 21.0	273.39	272.07	1.32
21°C for max; 4.4°C for min	279.08	272.01	7.07

Table 2. Summary of group delay system drift tests at strong signal level

Temperature, °C	Initial, ns	Final, ns	Change, ns	Elapsed time, h
S-band mean values for signal level 58 dB above threshold				
21.0	230.75	229.98	0.77	1.1
4.4	229.23	229.41	−0.18	1.3
34.0	230.76	230.60	0.16	1.5
Postcalibration, 21.0	229.32	229.17	0.15	1.3
X-band mean values for signal level 35 dB above threshold				
21.0	277.83	279.39	−1.56	2.1
4.4	273.65	274.40	−0.75	1.3
34.0	274.32	273.06	1.26	2.0
Postcalibration, 21.0	272.90	272.41	0.49	1.1

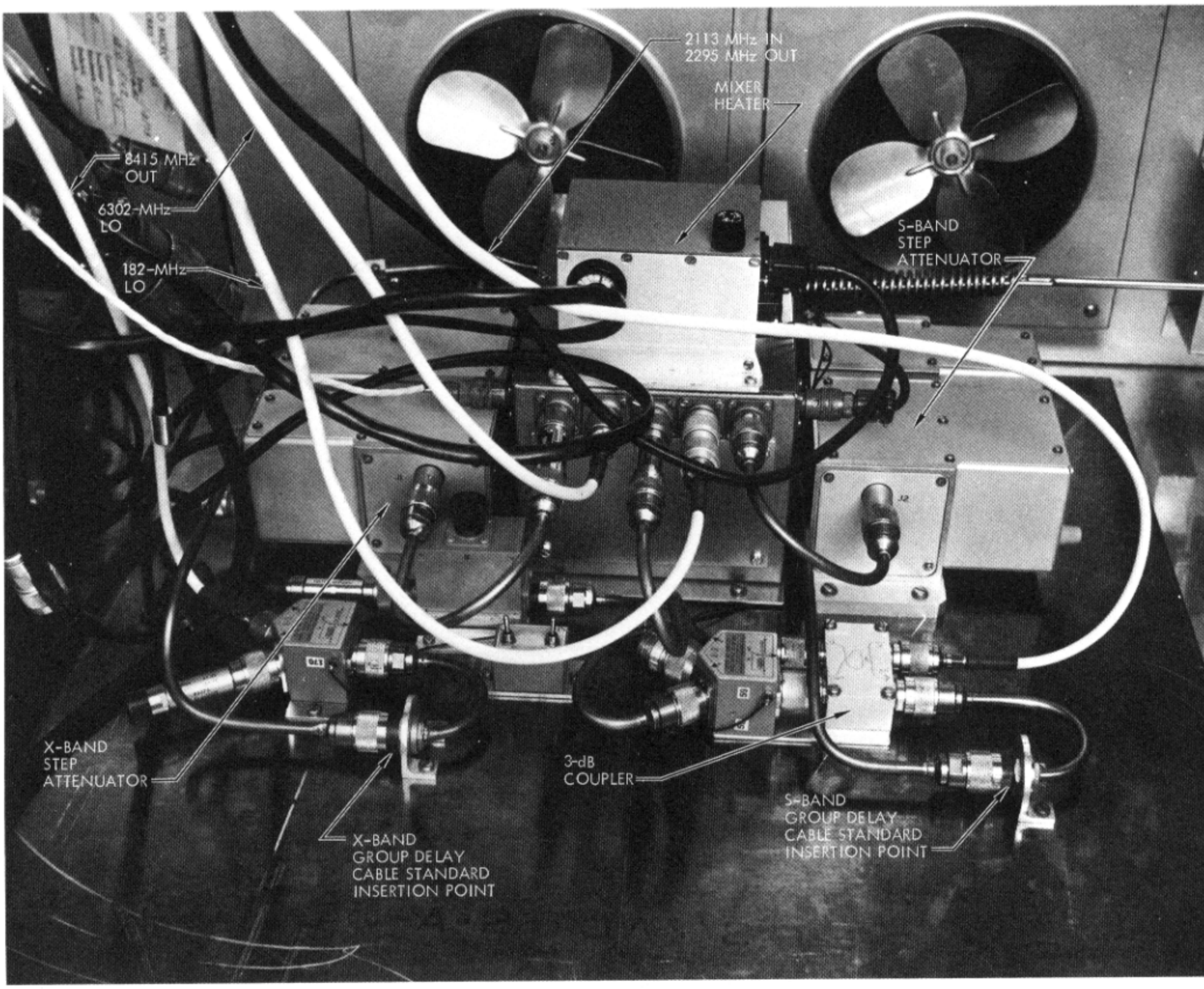

Fig. 1. Modified ZDD assembly in TDL temperature control chamber

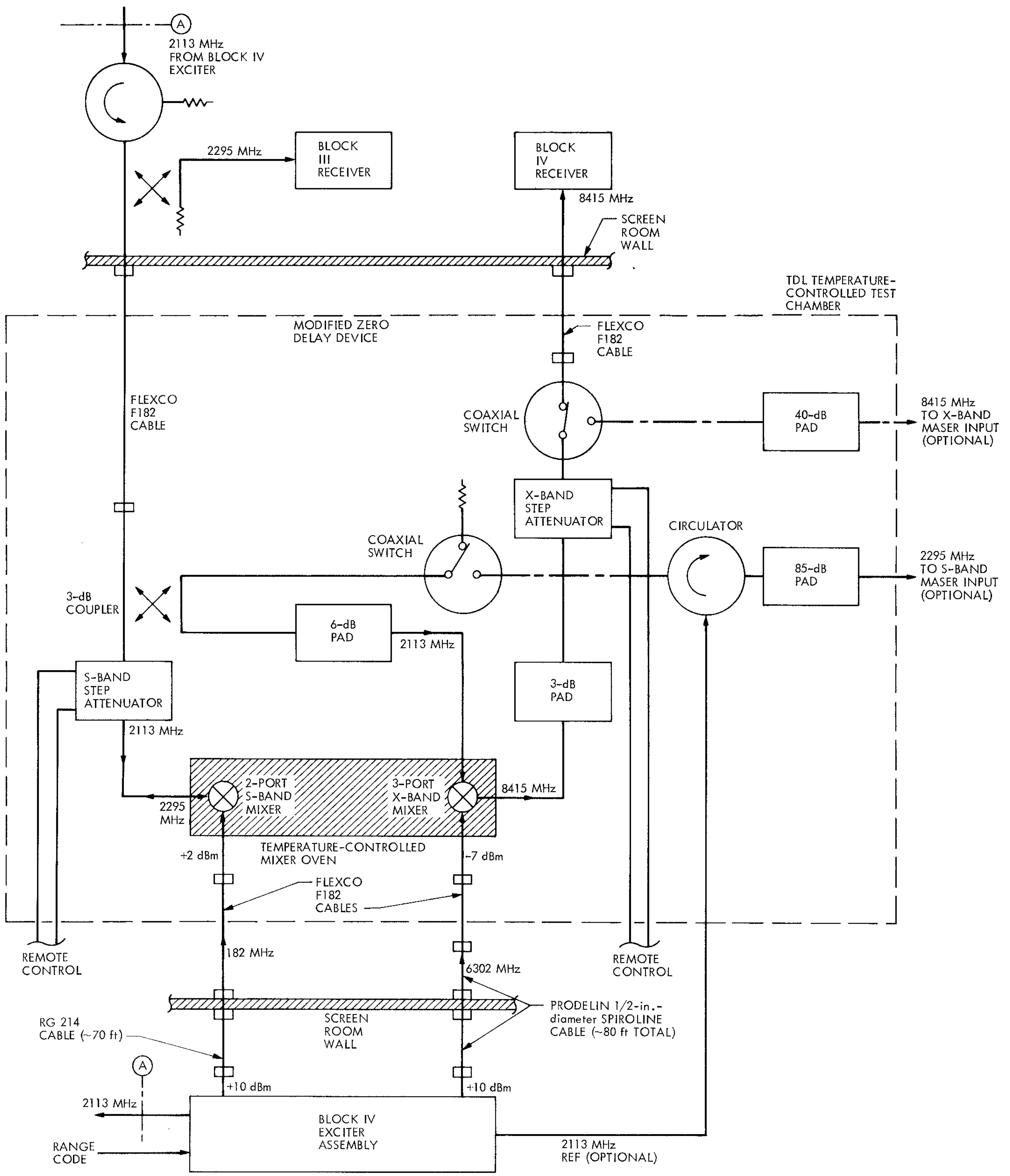

Fig. 2. Block diagram of test setup for ZDD tests at TDL

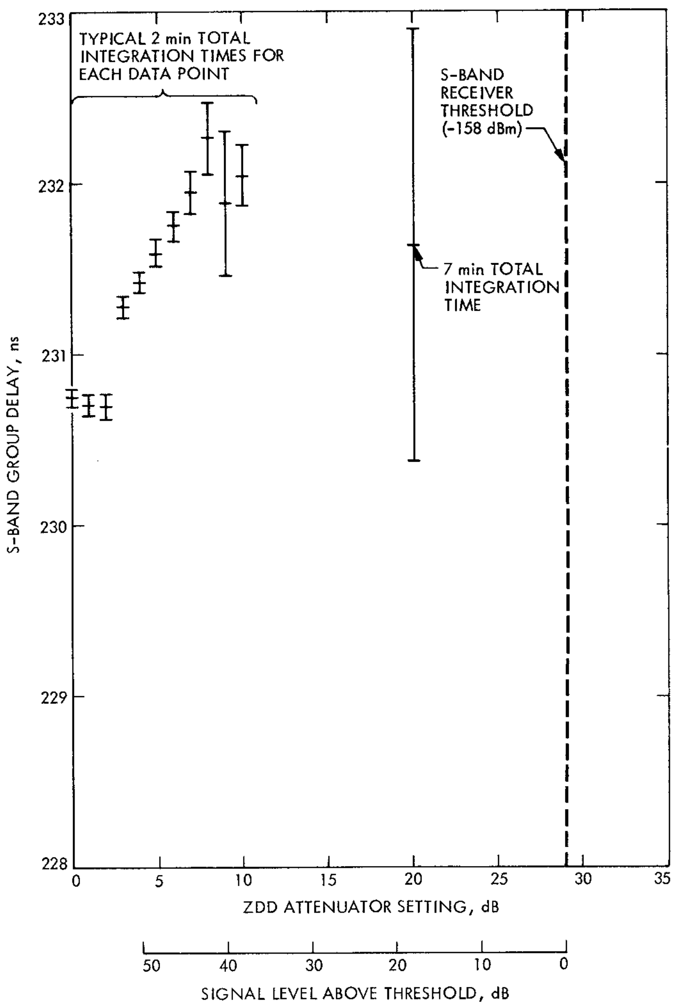

Fig. 3. Total system group delay via the 2113-MHz/2295-MHz path of the ZDD at 21°C

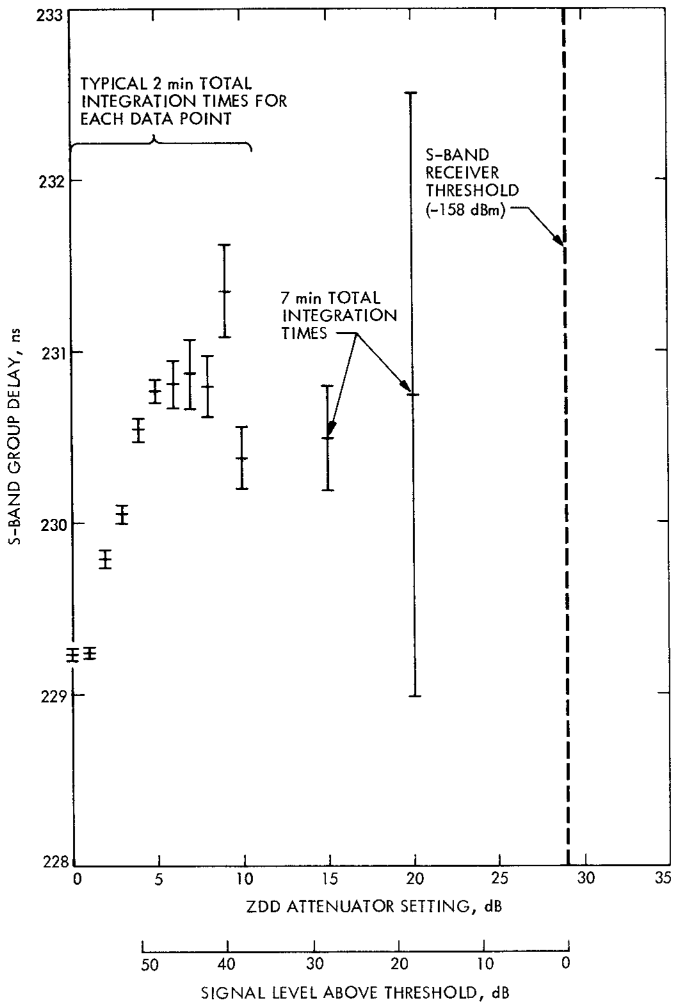

Fig. 4. Total system group delay via the 2113-MHz/2295-MHz path of the ZDD at 4.4°C

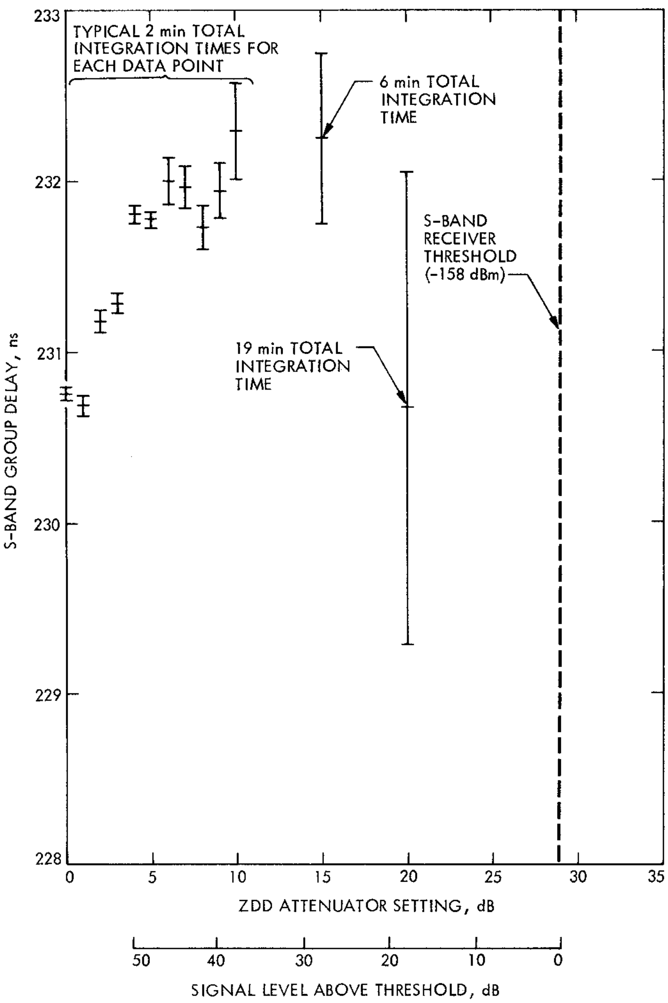

Fig. 5. Total system group delay via the 2113-MHz/2295-MHz path of the ZDD at 34°C

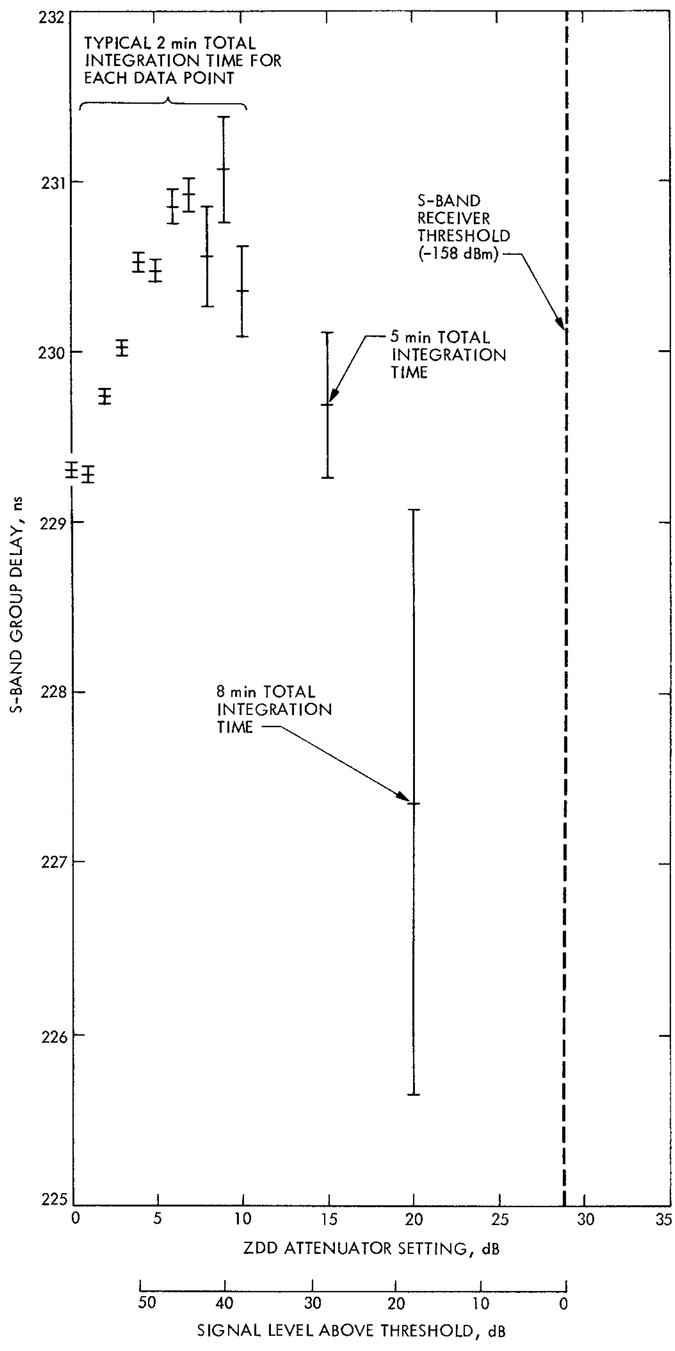

Fig. 6. Postcalibration of the total system group delay via the 2113-MHz/2295-MHz path of the ZDD at 21°C

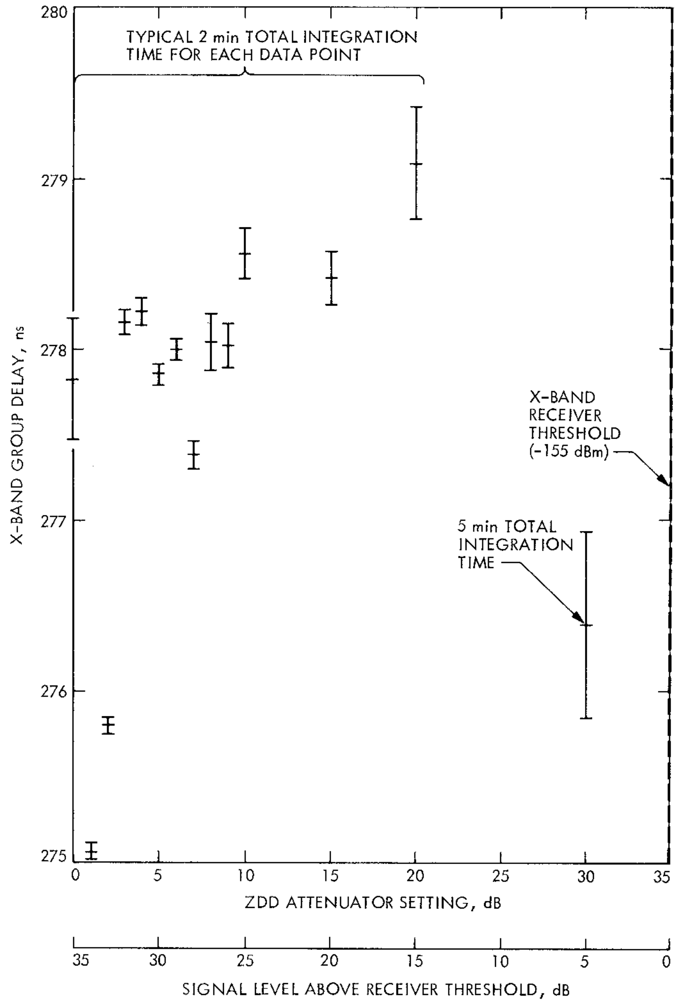

Fig. 7. Total system group delay via the 2113-MHz/8415-MHz path of the ZDD at 21°C

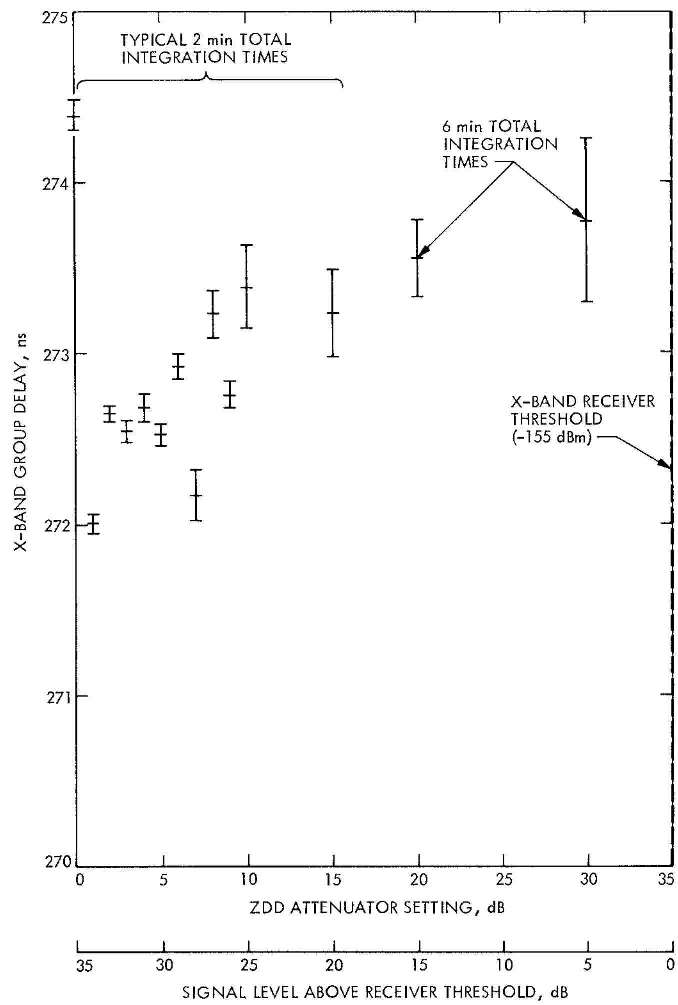

Fig. 8. Total system group delay via the 2113-MHz/8415-MHz path of the ZDD at 4.4°C

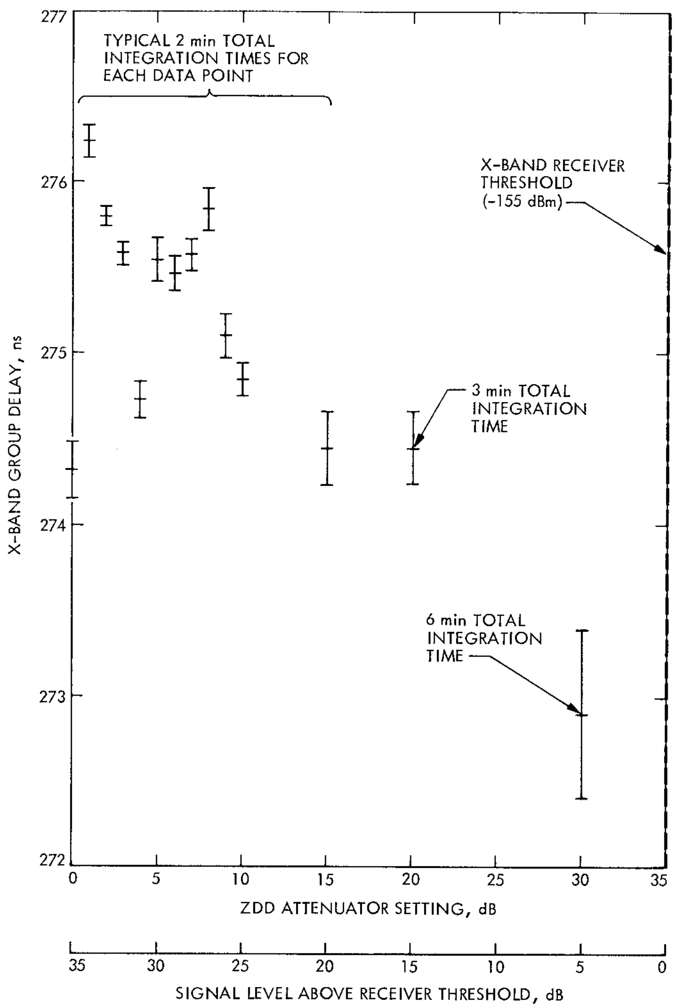

Fig. 9. Total system group delay via the 2113-MHz/8415-MHz path of the ZDD at 34°C

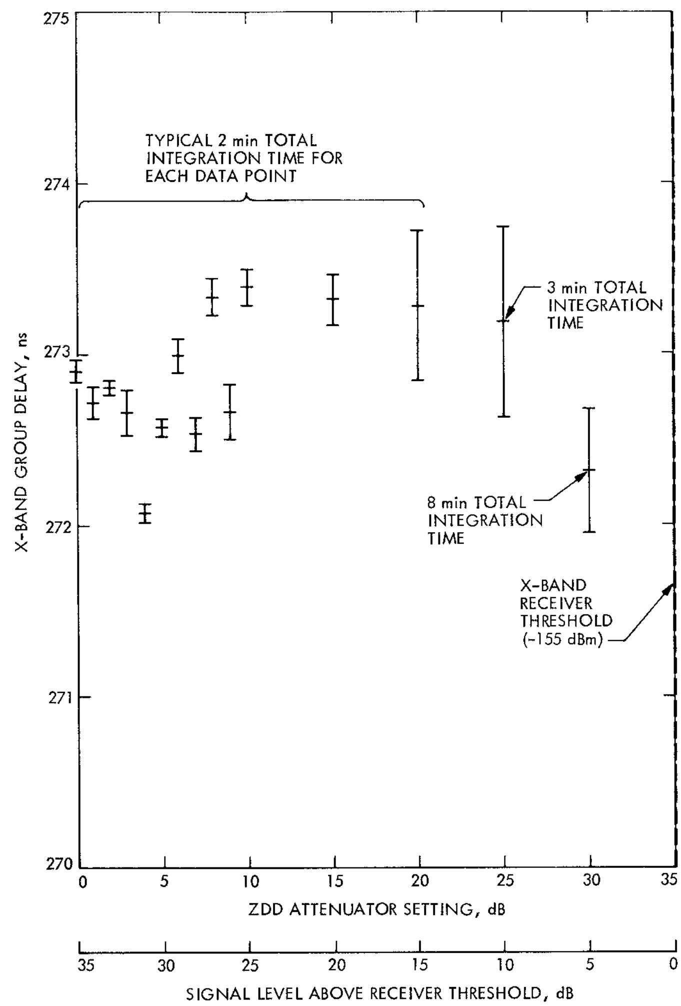

Fig. 10. Postcalibration of the total system group delay via the 2113-MHz/8415-MHz path of the ZDD at 21°C