S/X-Band Experiment: Zero-Delay-Device Step Attenuator Evaluation

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Test results are presented for a coaxial step attenuator to be used in the zero delay device for the S/X-band experiment. The test results at 182, 2113, 2295, 6302, and 8415 MHz indicate that the attenuator group delay changes about 0.07 ns over a 69-dB range. Tests made over a temperature range of 4.4°C (40°F) to 37.8°C (100°F) indicate that group delay and phase changes as a function of temperature are small.

I. Introduction

In Ref. 1, a zero delay device (ZDD) to be installed on the 64-m-diam antenna at DSS 14 was described. The ZDD is currently being developed for the S/X-band experiment to enable the group delay of the ground radio system to be calibrated, including the microwave antenna optics. Fig. 1 shows the step attenuator which will be used in the ZDD for purposes of varying signal levels. The attenuation of this device can be changed in 1-dB increments over a total dynamic range of 69 dB.

In the previous article (Ref. 1), some preliminary group delay and phase data were reported for the step attenuator at S- and X-band frequencies. Recently, the attenuator was also tested at 182 and 6302 MHz, which are the local oscillator frequencies for the S- and X-band mixers in the ZDD. This article will present these data, as well as data taken over a temperature range of 4.4°C (40°F) to 37.8°C (100°F).

II. Test Results

Table 1 shows a summary of the test results obtained on the step attenuator at 182, 2113, 2295, 6302, and 8415 MHz. The test data were obtained on a Hewlett-Packard 8542A Automatic Network Analyzer. The work was done by the Western Automatic Test Services of Palo Alto, California.

At higher attenuation settings in the region of 30 to 70 dB, it is known that the accuracy of the Automatic Network Analyzer becomes increasingly affected by noise. Therefore, it is not unusual to observe random fluctuations in the group delay data over the test frequency band. To overcome this problem, a least-squares linear fit was made to the phase data as a function of frequency over approximately 5% bandwidth frequency ranges. Group delay could then be calculated from the slope of the linear curve. This procedure was felt to be valid since it was already known (from data taken at lower attenuation settings) that the step attenuator has very broadband properties.

The test data in Table 1 can be summarized as follows:

(1) The transmission coefficient phase data indicate that the attenuator becomes electrically longer as attenuation increases.

(2) Group delay tends to increase with attenuation setting, in agreement with the test results described above in (1). Group delay changes about 0.07 ns over the attenuation range of 0 to 69 dB.

(3) The group delay and phase data changes with temperature do not appear to be correlated. However, changes of group delay and phase appear to be reasonably small over the temperature range of 4.4°C (40°F) to 37.8°C (100°F).

(4) The incremental phase shift increases linearly with frequency. Therefore, the incremental phase shifts at two different frequencies are related by the frequency ratio.

To clarify (4), let the incremental phase shift for a 2-port variable attenuator be expressed as

$$\Delta\psi_{21} = \psi_{21}(A_{dB}) - \psi_{21}(0) \tag{1}$$

where $\psi_{21}(A_{dB})$ and $\psi_{21}(0)$ are the transmission coefficient phases measured at an arbitrary attenuator setting A_{dB} and at a zero-dB setting, respectively. Then, if the incremental phase shift is known at one frequency, the incremental phase shift at another frequency can be calculated from the expression

$$(\Delta\psi_{21})_{f_1} = \frac{f_1}{f_2}(\Delta\psi_{21})_{f_2} \tag{2}$$

For example, from Table 1e it is found that, at 8415 MHz and 21.1°C, the incremental phase shift at the 10-dB setting is

$$(\Delta\psi_{21})_{8415} = -47.8 - 28.8 = -76.6 \text{ deg}$$

Then, the corresponding incremental phase shift at 182 MHz as calculated from Eq. (2) is

$$(\Delta\psi_{21})_{182} = \frac{182}{8415}(-76.6) = -1.7 \text{ deg}$$

From Table 1a, the actual measured incremental phase shift at the 10-dB setting is

$$(\Delta\psi_{21})_{182} = -63.5 - (-61.9) = -1.6 \text{ deg}$$

which is in good agreement with the calculated value. The data at other test frequencies and attenuation settings are generally in good agreement with those predicted by Eq. (2).

III. Concluding Remarks

Group delay and phase data for the ZDD coaxial step attenuator have been presented. It was shown that the device becomes electrically longer by approximately 0.07 ns when the attenuation increases from 0 to 69 dB. The changes in group delay and phase as a function of temperature were found to be reasonably small over the temperature range of 4.4 to 37.8°C.

Reference

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

Table 1. Test data for Weinschel model AE 97-69-3 step attenuator

Attenuator setting, dB	Group delay, ns			Transmission coefficient phase, deg		
	4.4°C	21.1°C	37.8°C	4.4°C	21.1°C	37.8°C
(a) 182 MHz						
0	1.03	0.95	1.02	−61.1	−61.9	−61.1
10	1.02	0.96	1.01	−63.0	−63.5	−62.9
15	1.05	0.98	1.04	−63.7	−64.1	−63.6
30	0.97	0.97	0.98	−63.6	−63.8	−63.5
60	1.01	1.00	1.00	−65.8	−65.8	−65.4
69	—	1.01	—	—	−64.8	—
(b) 2113 MHz						
0	0.95	0.94	0.96	7.4	3.8	7.4
10	1.02	0.97	1.03	−11.7	−15.5	−11.8
15	1.03	0.97	1.03	−17.8	−21.1	−17.3
30	0.98	0.97	0.98	−16.6	−20.0	−16.2
60	1.03	0.99	1.03	−33.2	−32.2	−32.7
69	—	1.00	—	—	−35.7	—
(c) 2295 MHz						
0	0.95	0.91	0.94	−54.0	−58.0	−54.1
10	1.00	0.96	0.99	−75.0	−78.7	−75.1
15	0.99	0.98	0.98	−81.7	−84.7	−81.1
30	0.97	0.97	0.97	−80.3	−83.6	−79.9
60	0.97	0.96	0.99	−99.8	−97.5	−98.6
69	—	0.99	—	—	−103.3	—
(d) 6302 MHz						
0	0.94	0.93	0.94	24.9	24.5	24.8
10	0.96	0.96	0.96	−32.5	−32.8	−33.0
15	0.97	0.97	0.98	−48.7	−48.6	−49.4
30	0.97	0.97	0.97	−47.7	−47.3	−47.7
60	1.01	0.99	0.98	−82.3	−80.5	−79.8
69	1.00	1.00	1.01	−96.8	−96.1	−93.9
(e) 8415 MHz						
0	0.94	0.93	0.94	29.5	28.8	29.0
10	0.95	0.95	0.94	−47.5	−47.8	−48.3
15	0.98	0.98	0.98	−69.6	−115.5	−70.5
30	0.97	0.97	0.97	−69.6	−69.5	−69.6
60	1.01	1.01	1.02	−118.0	−69.1	−114.4
69	0.99	1.01	1.02	−136.8	−134.4	−132.3

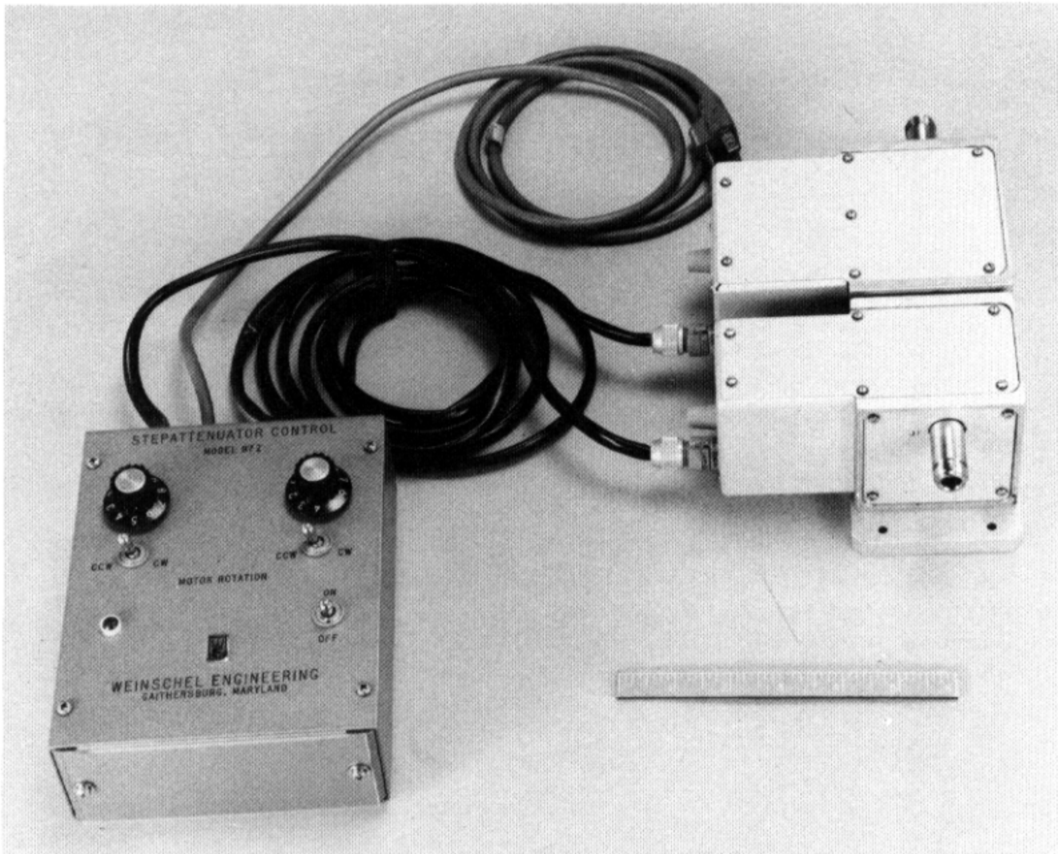

Fig. 1. Remotely controllable coaxial step attenuator, Weinschel Engineering Model AE 97-69-3