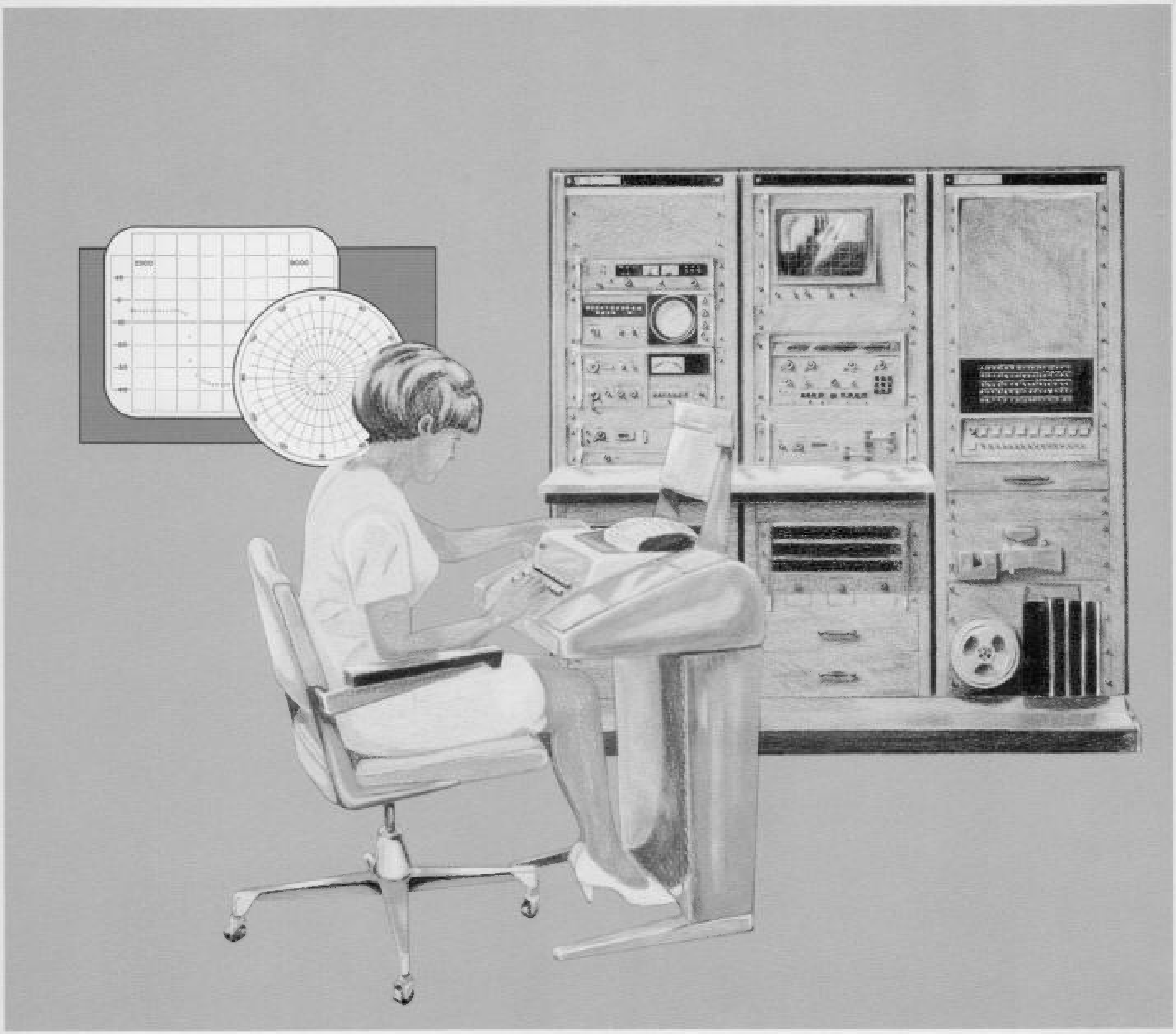
APPLICATION NOTE 99

8541A Automatic Network Analyzer Measurement Capabilities



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AUTOMATIC NETWORK ANALYZER MEASUREMENT CAPABILITIES

8541A

5951-0099 Printed: AUG 1968

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MEASUREMENT CAPABILITIES OF THE AUTOMATIC NETWORK ANALYZER USING STANDARD SOFTWARE

INTRODUCTION

This measurement note includes examples of measurements taken with a Hewlett-Packard 8540-series Automatic Network Analyzer operating in the 1 to 2 GHz range. The system is one of the simpler single-band versions and sells for approximately $70,000. The examples included are not all of the programs that are currently supplied with the system; however, they do show the overall system capabilities. Each of the programs has evolved because of specific application needs. A brief description of the programs is included below.

AGPR1

This program is the calibration portion of the BGPR1, CGPR1, and DGPR1 programs. Its self-check section allows a user to quickly check the calibration of his system by loading the program tape and checking a standard offset short circuit (a short circuit located a precise distance down a precision air line).

BGPR1

This program provides two-port measurements by reflection tests. A sliding load may be used to terminate the device so that its input impedance can be measured exactly. This makes the program useful for low-loss two-port devices such as cables and adapters.

CGPR1

This program is the most extensive of the reflection programs. Up to 125 measurement points may be displayed on an oscilloscope at one time. Manipulation of data is possible through different switch settings on the computer.

DGPR1

This program provides high-precision real-time reflection measurements. As a device is inserted or adjusted, the results can be seen within a few seconds. This program provides the most usable means for adjusting or changing hardware and simultaneously observing the affects.

REFL1

This program provides simplified versions of the same functions provided by programs AGPR1 and CGPR1. Calibration and measurements are included in the same software package.

TRAN2

This program provides real-time transmission measurements of group delay, insertion loss in dB and phase/gain data.

TRAN3

More extensive measurements of total phase shift, deviation from linear phase shift and deviation from linear gain/loss through two-port devices are included in this program.

CALIBRATION FOR GENERAL-PURPOSE REFLECTION PROGRAMS

CALIBRATION PROGRAM USED: AGPR1

MEASUREMENT DATA OBTAINED: None

TYPE OF MEASUREMENT: Calibration for BGPR1, CGPR1, DGPR1 programs

MEASUREMENT RESULTS: AGPR1 is the calibration program for the system and must be used before using the general-purpose reflection programs BGPR1, CGPR1 or DGPR1.

The program begins by asking the question:

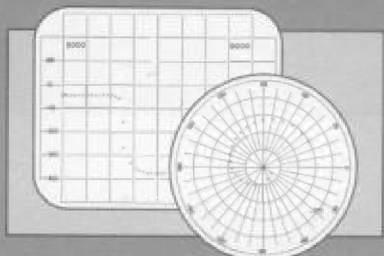
SELF CHECK ONLY?

This question is used to check the calibration of the system. The first time the question is asked, the response is NO. The program then proceeds through calibration of the system using a 50-ohm load (preferably a sliding type), a short circuit, and several different offset shorts (short circuits at the end of a precision air line of known length).

Any time after the initial calibration, return can be made to the calibration portion of the program and the question

SELF CHECK ONLY?

Answered YES: the system tells the operator to insert a standard offset short circuit different from the one used for calibration into the system and quickly checks the system calibration. The system then is ready to use any of the BGPR1, CGPR1 or DGPR1 general-purpose reflection programs.



REFLECTION MEASUREMENT

MEASUREMENT OF AN RF COAXIAL CABLE

MEASUREMENT PROGRAM USED: BGPR1

MEASUREMENT DATA OBTAINED:

Teletype Printout

s_{11}

VSWR

Reflection Coefficient

s_{22}

VSWR

Reflection Coefficient

s_{12} or s_{21}

Loss in dB (One Direction)

Two times Phase Shift (both directions)

TYPE OF MEASUREMENT: Passive two-port

MEASUREMENT RESULTS: The test device in this example is 33 feet of RF coaxial cable which is terminated with a standard load, a standard short, and an offset short circuit.

Teletype Printout

Figure 1 is a printout of the data obtained characterizing the cable. Frequency steps of 50 MHz were chosen for measurement although smaller steps could have been used.

MEASUREMENT OF A DEFECTIVE 20-dB ATTENUATOR

MEASUREMENT PROGRAM USED: CGPR1

MEASUREMENT DATA OBTAINED:

Oscilloscope Display

Magnitude and Phase Angle of Reflection Coefficient Reflection Coefficient $|\rho|$ versus Frequency

Teletype Printout

Magnitude and Phase Angle of Reflection Coefficient

VSWR

Return Loss in dB

Impedance

Admittance

TYPE OF MEASUREMENT: Reflection

MEASUREMENT RESULTS: Program AGPR1 is first used to calibrate the system and then program CGPR1 is used. The test device is a 20-dB attenuator which has a defective section in its network.

Oscilloscope Display

Magnitude and Phase Angle of Reflection Coefficient

Figure 2 shows the magnitude and phase angle of the reflection coefficient looking into the good end of the attenuator. The frequency increases in a clockwise direction from 1000 MHz to 2000 MHz. Figure 3 shows the same information looking into the defective end of the attenuator. Figure 4 shows the same information looking into the defective end of the attenuator with the phase reference shifted to the plane of the discontinuity. This measurement program is capable of mathematically rotating the Smith Chart reference plane assuming a lossless airline whose characteristic impedance is equal to that of the system, or a simulated lossless waveguide section whose cutoff frequency is equal to that of the system.

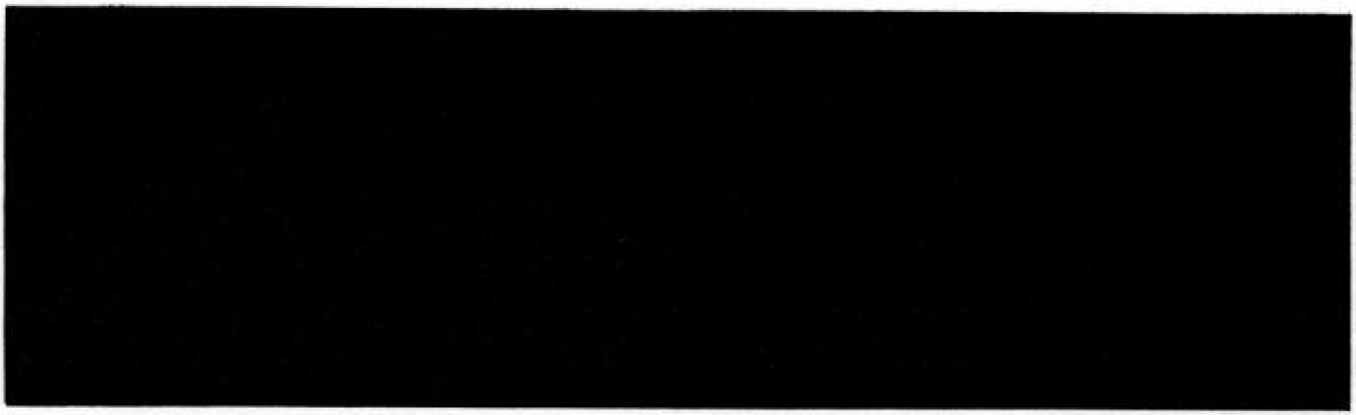
Reflection Coefficient $|\rho|$ versus Frequency

Figure 5 displays the absolute value of the reflection coefficient $|\rho|$ versus frequency looking into the good end of the attenuator. Figure 6 shows the same information looking into the defective end. In each case the value displayed (.05, 1.0) is the full scale magnitude. The base line represents the minimum value. The top graticule represents the full scale value. The X-axis represents frequency, (1000 to 2000 MHz, left to right).

Teletype Printout

Reflection Coefficient

VSWR and Return Loss



FREQ	S11			S22			S12 OR S21	
	VSWR	REFL COEF		VSWR	REFL COEF		DB	2*ANG
1000	1.062	.0303	-20.3	1.096	.0457	53.5	-2.73	102.7
1050	1.013	.0064	21.0	1.184	.0840	-115.4	-3.07	159.5
1100	1.075	.0361	-37.8	1.397	.1658	-114.1	-3.29	-72.8
1150	1.015	.0074	7.0	1.037	.0183	-114.2	-3.14	139.3
1200	1.063	.0305	-37.5	1.169	.0779	-104.1	-3.30	156.9
1250	1.086	.0412	-52.5	1.196	.0894	-95.6	-3.36	56.9
1300	1.092	.0439	-73.6	1.110	.0522	63.4	-3.28	39.8
1350	1.003	.0013	128.7	1.043	.0210	-95.7	-3.45	-150.5
1400	1.083	.0396	-82.6	1.125	.0590	-103.3	-3.55	-42.7
1450	1.004	.0022	-90.0	1.148	.0638	-105.2	-3.64	156.8
1500	1.078	.0374	-78.9	1.108	.0513	-100.7	-3.71	100.1
1550	1.028	.0137	-98.0	1.064	.0310	-117.7	-3.78	-115.8
1600	1.110	.0520	-110.9	1.047	.0231	-128.9	-3.87	-54.8
1650	1.025	.0122	-129.0	1.027	.0135	-171.0	-3.95	-88.2
1700	1.097	.0461	-129.2	1.072	.0349	162.7	-4.05	169.3
1750	1.030	.0146	-105.1	1.029	.0144	172.0	-4.13	-33.3
1800	1.086	.0413	-141.3	1.062	.0299	-113.0	-4.17	-26.7
1850	1.015	.0075	-93.8	1.043	.0212	-153.4	-4.25	-79.8
1900	1.098	.0469	-145.2	1.103	.0491	-153.1	-4.34	-155.2
1950	1.038	.0184	-169.4	1.063	.0308	-127.2	-4.37	102.1
2000	1.081	.0390	170.0	1.095	.0455	165.7	-4.51	86.7

Figure 1. Teletype Printout Showing Test Parameters of a Coaxial Cable

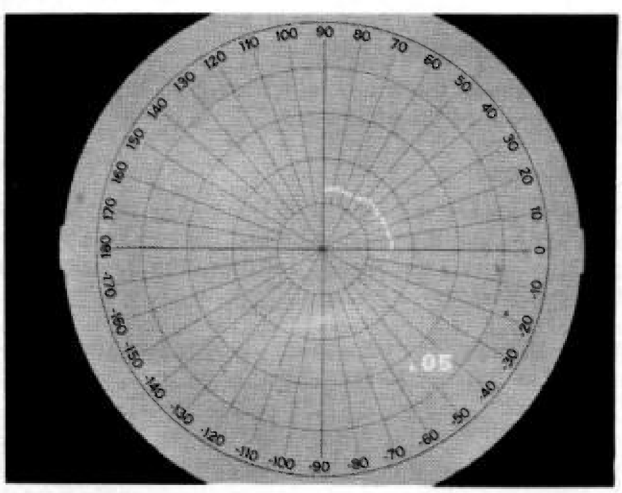


Figure 2. Reflection Coefficient Data Showing Good End of a 20-dB Attenuator

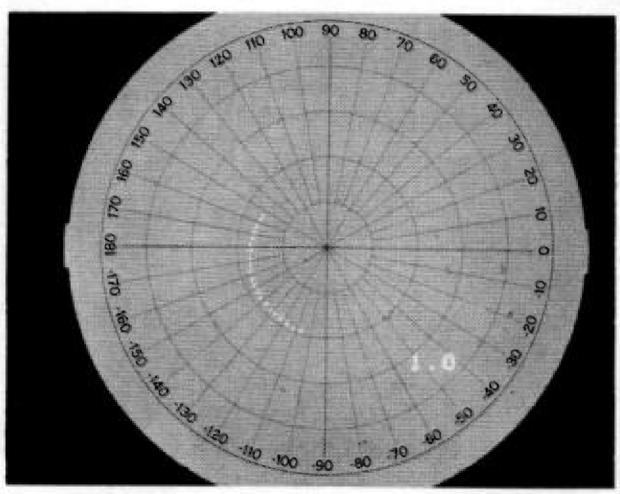
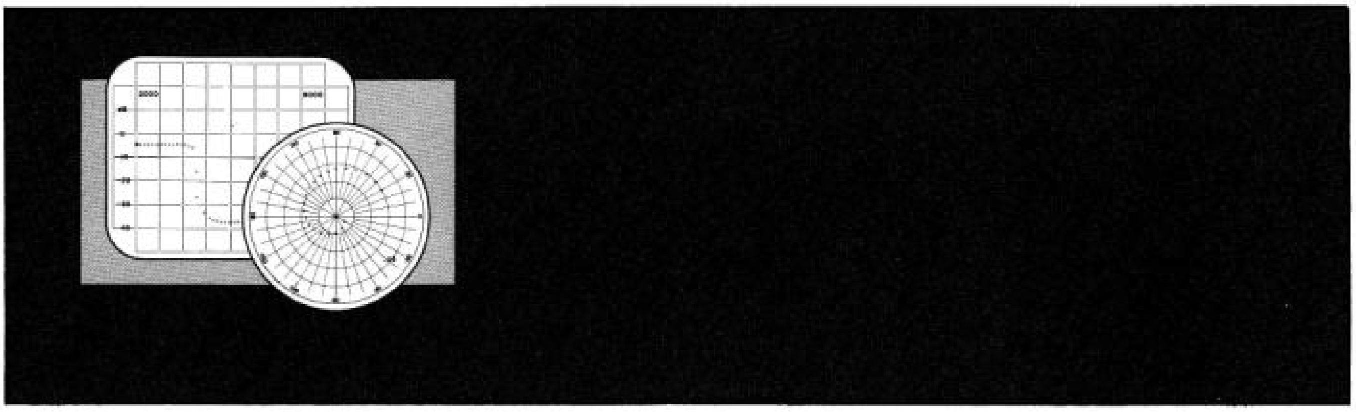


Figure 3. Reflection Coefficient Data Showing Defective End of a 20-dB Attenuator



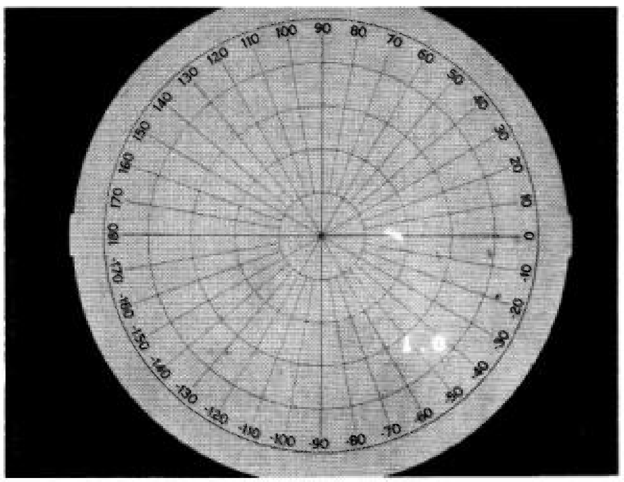


Figure 4. Reflection Coefficient Data Showing Defective End of a 20-dB Attenuator with the Phase Reference Plane Shifted to the Plane of the Discontinuity

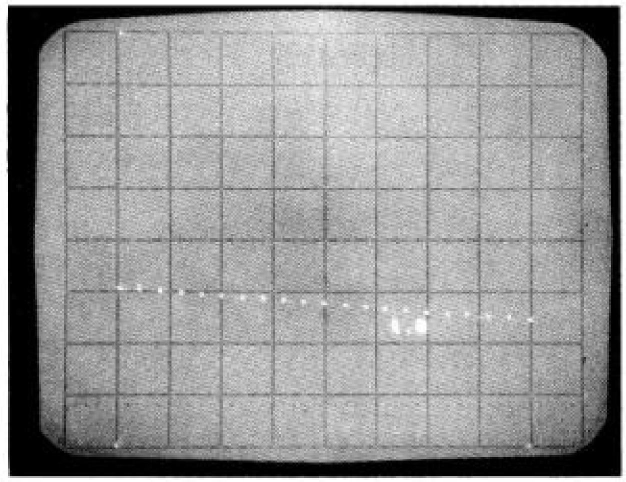


Figure 6. Absolute Value of the Reflection Coefficient Versus Frequency of the Defective End of a 20-dB Attenuator

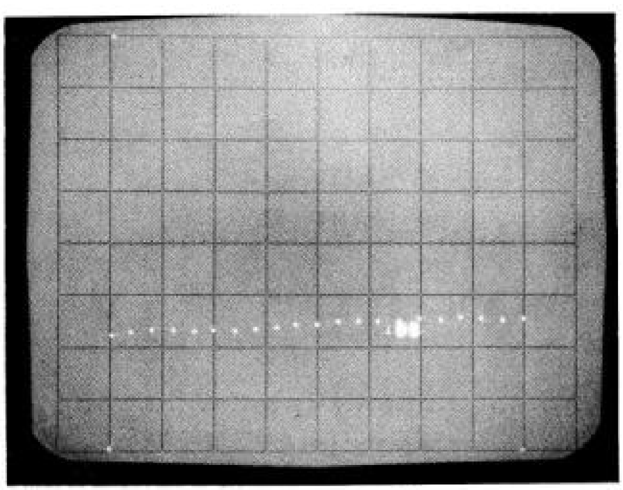


Figure 5. Absolute Value of the Reflection Coefficient Versus Frequency of the Good End of a 20-dB Attenuator

Figure 7 shows the reflection coefficient data, VSWR and return loss in dB obtained looking into the good end of the attenuator.

Figure 8 shows the same information looking into the defective end of the attenuator.

Impedance

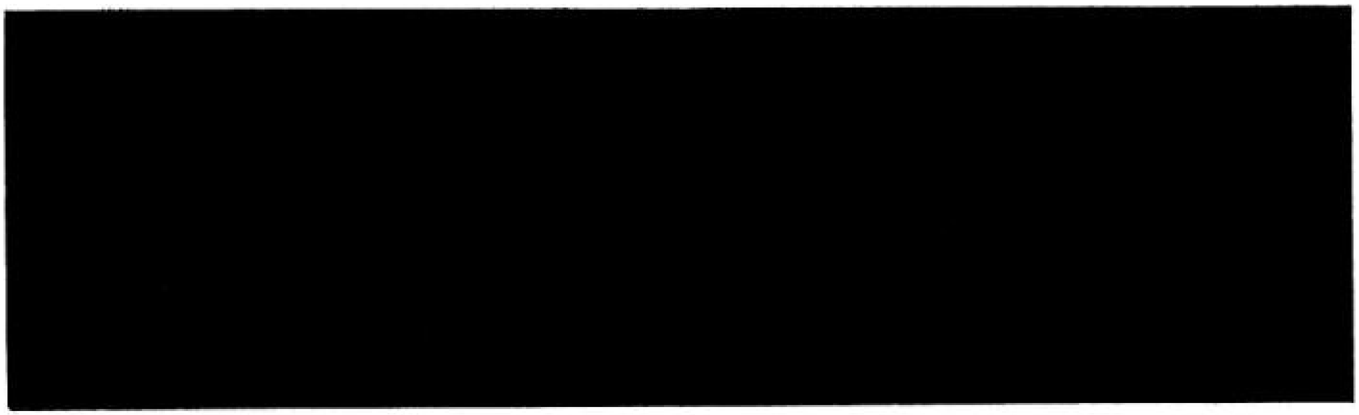
Figure 9 shows the real and imaginary parts of the impedance, and the magnitude and phase angle vector quantities of the impedance looking into the good end of the attenuator.

Figure 10 shows the impedance looking into the defective end of the attenuator.

Admittance

Figure 11 shows the real and imaginary parts of the admittance, and the magnitude and phase angle vector quantities of the admittance looking into the good end of the attenuator.

Figure 12 shows the admittance looking into the defective end of the attenuator.

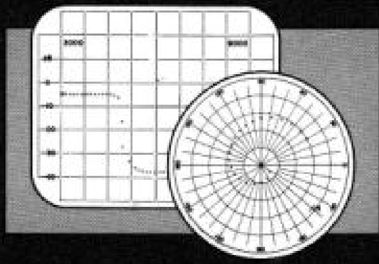


FREQ	REFL: MAGN	ANGLE	VSWR	RTN LOSS
1000.0	.0132	84.3	1.027	37.61
1050.0	.0136	78.9	1.027	37.36
1100.0	.0138	76.6	1.028	37.22
1150.0	.0138	73.1	1.028	37.21
1200.0	.0140	69.5	1.028	37.09
1250.0	.0141	66.5	1.029	37.04
1300.0	.0140	62.0	1.028	37.05
1350.0	.0141	56.9	1.029	37.02
1400.0	.0144	51.8	1.029	36.84
1450.0	.0145	47.5	1.029	36.77
1500.0	.0149	42.6	1.030	36.52
1550.0	.0150	38.2	1.031	36.46
1600.0	.0151	35.1	1.031	36.39
1650.0	.0151	32.5	1.031	36.44
1700.0	.0151	28.9	1.031	36.43
1750.0	.0149	26.2	1.030	36.52
1800.0	.0150	22.5	1.030	36.50
1850.0	.0149	17.9	1.030	36.52
1900.0	.0155	11.2	1.031	36.20
1950.0	.0155	6.7	1.031	36.19
2000.0	.0160	2.1	1.033	35.91

Figure 7. Teletype Printout Looking into the Good End of a Defective Attenuator

FREQ	REFL: MAGN	ANGLE	VSWR	RTN LOSS
1000.0	.3768	-104.5	2.209	8.48
1050.0	.3763	-110.4	2.207	8.49
1100.0	.3718	-115.7	2.184	8.59
1150.0	.3679	-121.1	2.164	8.69
1200.0	.3623	-126.2	2.136	8.82
1250.0	.3571	-131.3	2.111	8.94
1300.0	.3565	-136.4	2.108	8.96
1350.0	.3539	-141.7	2.096	9.02
1400.0	.3493	-146.4	2.074	9.14
1450.0	.3469	-151.7	2.062	9.20
1500.0	.3443	-157.0	2.050	9.26
1550.0	.3400	-162.7	2.030	9.37
1600.0	.3360	-167.6	2.021	9.42
1650.0	.3328	-172.6	1.998	9.56
1700.0	.3305	-177.7	1.987	9.62
1750.0	.3261	177.3	1.968	9.73
1800.0	.3215	172.0	1.948	9.86
1850.0	.3169	166.9	1.928	9.98
1900.0	.3150	161.6	1.920	10.03
1950.0	.3059	157.4	1.881	10.29
2000.0	.3054	152.0	1.879	10.30

Figure 8. Teletype Printout Looking into the Bad End of a Defective Attenuator

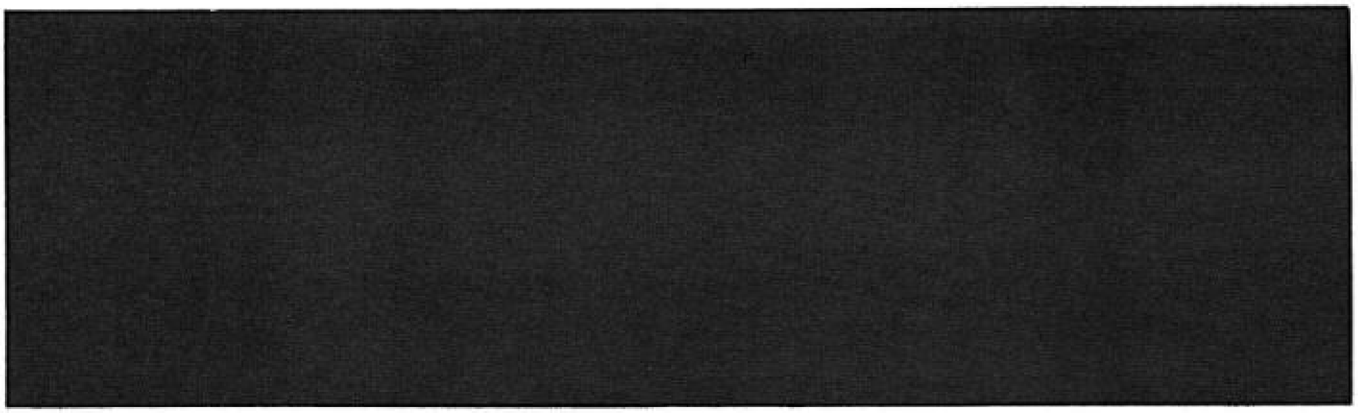


Z	FREQ	REAL	IMAG	MAGN	ANGLE
	1000.0	50.113	1.313	50.130	1.5
	1050.0	50.243	1.337	50.261	1.5
	1100.0	50.303	1.348	50.321	1.5
	1150.0	50.384	1.330	50.402	1.5
	1200.0	50.475	1.323	50.492	1.5
	1250.0	50.546	1.304	50.563	1.5
	1300.0	50.649	1.256	50.664	1.4
	1350.0	50.762	1.198	50.776	1.4
	1400.0	50.885	1.150	50.898	1.3
	1450.0	50.978	1.091	50.990	1.2
	1500.0	51.102	1.032	51.112	1.2
	1550.0	51.185	.952	51.194	1.1
	1600.0	51.248	.392	51.255	1.0
	1650.0	51.280	.831	51.286	.9
	1700.0	51.332	.750	51.338	.8
	1750.0	51.354	.673	51.358	.6
	1800.0	51.396	.596	51.399	.7
	1850.0	51.436	.473	51.440	.5
	1900.0	51.543	.309	51.543	.3
	1950.0	51.564	.186	51.564	.2
	2000.0	51.626	.062	51.626	.1

Figure 9. Impedance of a Defective Attenuator Looking into the Good End

Z	FREQ	REAL	IMAG	MAGN	ANGLE
	1000.0	32.237	-27.412	42.316	-40.4
	1050.0	30.562	-25.107	39.552	-39.4
	1100.0	29.487	-22.919	37.347	-37.9
	1150.0	28.525	-20.754	35.294	-36.1
	1200.0	27.856	-18.752	33.559	-33.9
	1250.0	27.282	-16.780	32.039	-31.6
	1300.0	26.564	-14.972	30.492	-29.4
	1350.0	26.024	-13.054	29.115	-26.6
	1400.0	25.759	-11.331	28.141	-23.7
	1450.0	25.410	-9.515	27.133	-20.5
	1500.0	25.150	-7.687	26.298	-17.0
	1550.0	25.057	-5.729	25.704	-12.9
	1600.0	24.955	-4.074	25.286	-9.3
	1650.0	25.109	-2.434	25.227	-5.5
	1700.0	25.169	-.752	25.180	-1.7
	1750.0	25.422	.365	25.437	1.9
	1800.0	25.762	2.574	25.890	5.7
	1850.0	26.184	4.168	26.513	9.0
	1900.0	26.540	5.857	27.179	12.4
	1950.0	27.333	7.098	28.240	14.6
	2000.0	27.770	8.771	29.122	17.5

Figure 10. Impedance of a Defective Attenuator Looking into the Good End

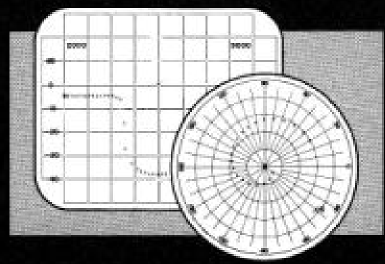


Y	FREQ	REAL	IMAG	MAGN	ANGLE
	1000.0	.020	-.001	.020	-1.5
	1050.0	.020	-.001	.020	-1.5
	1100.0	.020	-.001	.020	-1.5
	1150.0	.020	-.001	.020	-1.5
	1200.0	.020	-.001	.020	-1.5
	1250.0	.020	-.001	.020	-1.5
	1300.0	.020	-.000	.020	-1.4
	1350.0	.020	-.000	.020	-1.4
	1400.0	.020	-.000	.020	-1.3
	1450.0	.020	-.000	.020	-1.2
	1500.0	.020	-.000	.020	-1.2
	1550.0	.020	-.000	.020	-1.1
	1600.0	.020	-.000	.020	-1.0
	1650.0	.019	-.000	.019	-.9
	1700.0	.019	-.000	.019	-.8
	1750.0	.019	-.000	.019	-.8
	1800.0	.019	-.000	.019	-.7
	1850.0	.019	-.000	.019	-.5
	1900.0	.019	-.000	.019	-.3
	1950.0	.019	-.000	.019	-.2
	2000.0	.019	-.000	.019	-.1

Figure 11. Admittance of a Defective Attenuator Looking into the Good End

Y	FREQ	REAL	IMAG	MAGN	ANGLE
	1000.0	.018	.015	.024	40.4
	1050.0	.020	.016	.025	39.4
	1100.0	.021	.016	.027	37.9
	1150.0	.023	.017	.028	36.1
	1200.0	.025	.017	.030	33.9
	1250.0	.027	.016	.031	31.6
	1300.0	.029	.016	.033	29.4
	1350.0	.031	.015	.034	26.6
	1400.0	.033	.014	.036	23.7
	1450.0	.035	.013	.037	20.5
	1500.0	.036	.011	.038	17.0
	1550.0	.038	.009	.039	12.9
	1600.0	.039	.006	.040	9.3
	1650.0	.039	.004	.040	5.5
	1700.0	.040	.001	.040	1.7
	1750.0	.039	-.001	.039	-1.9
	1800.0	.038	-.004	.039	-5.7
	1850.0	.037	-.006	.038	-9.0
	1900.0	.036	-.008	.037	-12.4
	1950.0	.034	-.009	.035	-14.6
	2000.0	.033	-.010	.034	-17.5

Figure 12. Admittance of a Defective Attenuator Looking into the Bad End



REFLECTION MEASUREMENT

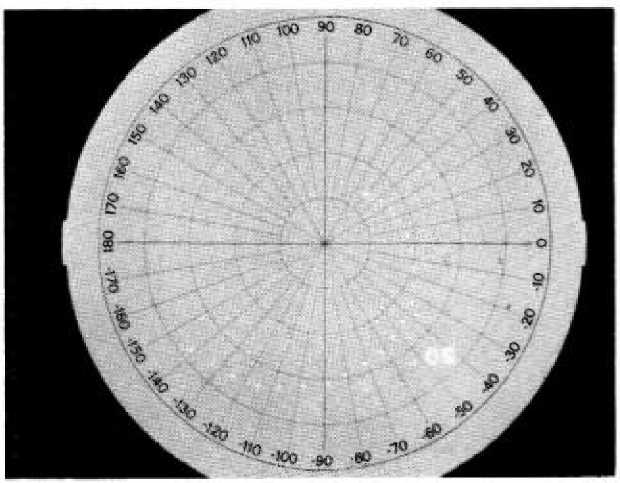


Figure 13. Reflection Coefficient of Biased Thermistor

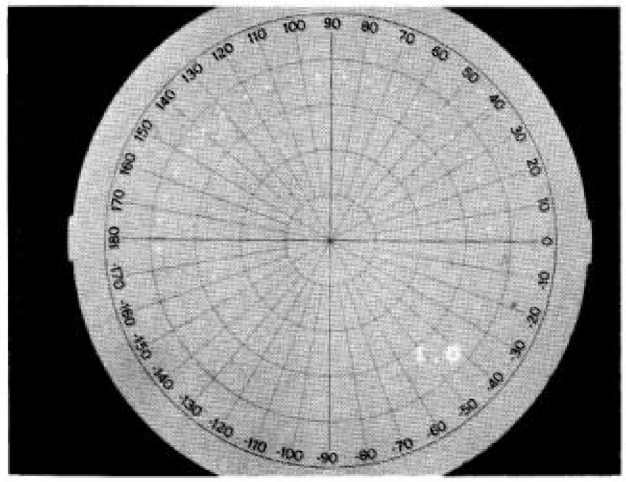


Figure 14. Reflection Coefficient of Unbiased Thermistor

MEASUREMENT OF A BIASED AND UNBIASED THERMISTOR MOUNT

MEASUREMENT PROGRAM USED: DGPR1

MEASUREMENT DATA OBTAINED:

Oscilloscope Display

Magnitude and Phase of Reflection Coefficient

Teletype Printout

Impedance (Real and Imaginary Parts)

Reflection Coefficient (Magnitude and Phase Angle)

TYPE OF MEASUREMENT: Real - time reflection

MEASUREMENT RESULTS: Program AGPR1 is first used to calibrate the system and then program DGPR1 is used.

All measurement data is obtained on a real-time basis at full system accuracy. As a test device is inserted into the system, its affect on measurement data is immediately displayed. This permits easy adjustment or manipulation of test devices.

Oscilloscope Display

Magnitude and Phase of Reflection Coefficient

Figure 13 shows the results obtained with a 50-ohm normalized polar display (Smith Chart). The system automatically selects the full scale reflection coefficient for best resolution. In this example, the scale chosen was . 05 reflection at the outer graticule ring.

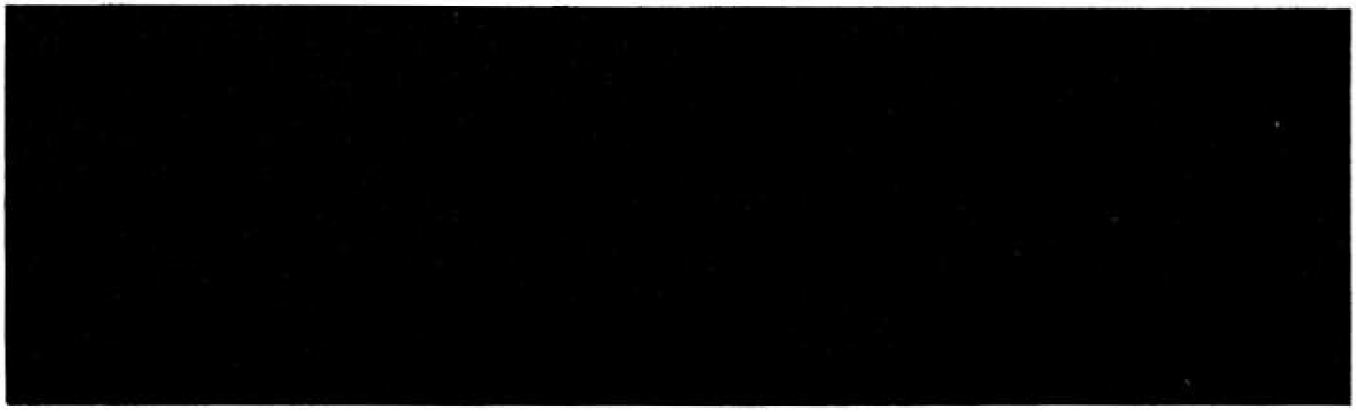
In Figure 14, the thermistor was left unbiased and a different reflection coefficient value was displayed.

Figure 15 is a display of the biased thermistor mount on a Smith Chart normalized to 75 ohms.

Teletype Printout

Impedance (Real and Imaginary Parts)

Reflection Coefficient (Magnitude and Phase Angle)



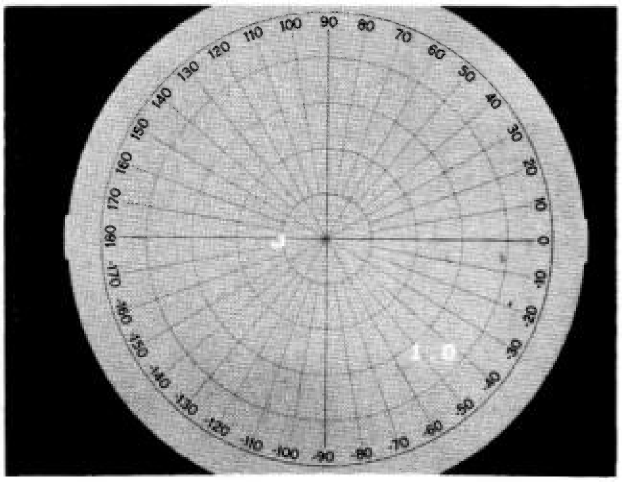


Figure 15. Reflection Coefficient of Biased Thermistor (Display Normalized to 75 ohms)

SMITH CHART NORMALIZED TO:	50.0			
FREQ	IMPEDANCE		REFLECTION COEF	
	REAL	IMAG	MAGN	ANGLE
1000.0	50.9	1.2	.015	50.5
1050.0	51.3	1.0	.016	38.2
1100.0	51.5	.8	.017	28.5
1150.0	51.7	.5	.018	17.2
1200.0	51.9	.2	.019	6.4
1250.0	52.0	-.1	.020	-3.9
1300.0	52.0	-.5	.021	-14.0
1350.0	52.0	-1.0	.022	-24.6
1400.0	52.0	-1.3	.023	-33.4
1450.0	51.8	-1.7	.025	-43.3
1500.0	51.5	-2.1	.026	-52.4
1550.0	51.2	-2.4	.027	-62.1
1600.0	50.8	-2.7	.028	-71.0
1650.0	50.4	-2.9	.029	-79.7
1700.0	50.0	-3.0	.030	-88.5
1750.0	49.5	-3.1	.031	-98.1
1800.0	49.0	-3.1	.033	-106.9
1850.0	48.5	-3.0	.034	-115.6
1900.0	48.0	-2.8	.035	-124.4
1950.0	47.5	-2.5	.036	-133.1
2000.0	47.1	-2.2	.037	-141.4

Figure 16. Smith Chart Normalized to 50 ohms Showing Impedance and Reflection Coefficient Data (Biased Thermistor Mount)

Figure 16 is a printout of the impedance and reflection coefficient of the biased thermistor for a 50-ohm Smith Chart.

Figure 17 is a printout of measurement data when the Smith Chart was normalized to 75 ohms. Note that the impedance stays the same but the reflection coefficient changes according to the normalizing impedance

Figure 18 is a printout of the impedance and reflection coefficient of the unbiased thermistor mount with a 50-ohm normalized Smith Chart.

MEASUREMENT OF A 3-dB ATTENUATOR

MEASUREMENT PROGRAM USED: REFL1

MEASUREMENT DATA OBTAINED:

Oscilloscope Display

Magnitude and Phase Reflection Coefficient

Teletype Printout

Magnitude and Phase of Reflection Coefficient

VSWR

Return Loss in dB

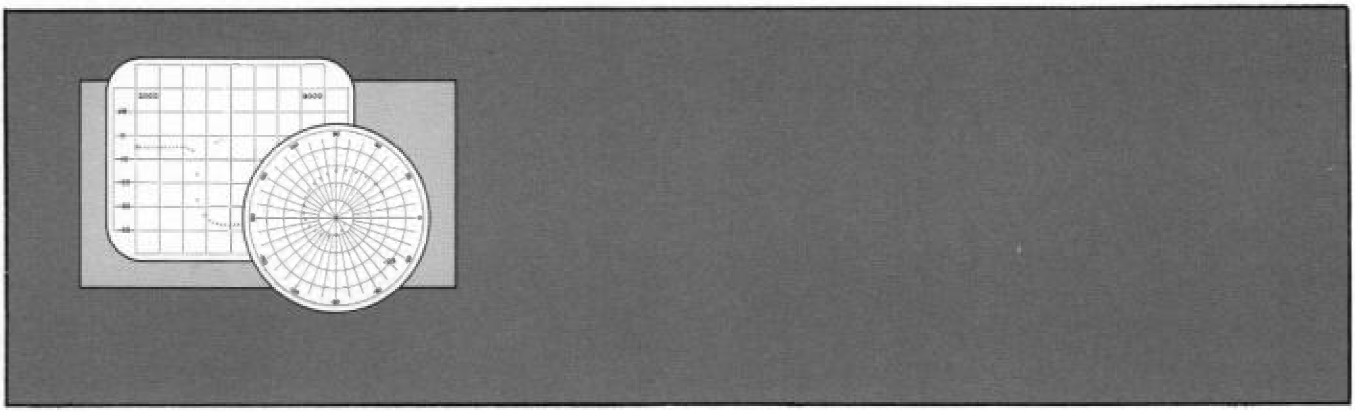
TYPE OF MEASUREMENT: Reflection

MEASUREMENT RESULTS: The program begins by calibrating the system. First the frequency range is asked for with the frequency intervals in MHz. A 50-ohm load (preferably a sliding type), a short, and several different offset shorts are used for characterizing the system errors.

Oscilloscope Display

Reflection Coefficient

Figure 19 is a display of the magnitude and phase of the reflection coefficient of a 3-dB attenuator



SMITH CHART NORMALIZED TO: 75.0				
FREQ	IMPEDANCE		REFLECTION COEF	
	REAL	IMAG	MAGN	ANGLE
1000.0	51.0	1.1	.191	176.8
1050.0	51.3	1.0	.188	177.1
1100.0	51.5	.8	.186	177.6
1150.0	51.7	.5	.184	178.4
1200.0	51.9	.2	.182	179.4
1250.0	52.0	-.1	.181	-179.6
1300.0	52.0	-.5	.181	-178.5
1350.0	52.0	-1.0	.181	-177.2
1400.0	52.0	-1.3	.182	-176.1
1450.0	51.8	-1.7	.183	-174.9
1500.0	51.5	-2.1	.186	-174.0
1550.0	51.2	-2.4	.189	-173.1
1600.0	50.8	-2.7	.193	-172.5
1650.0	50.4	-2.9	.197	-172.0
1700.0	50.0	-3.0	.202	-171.7
1750.0	49.5	-3.1	.207	-171.7
1800.0	49.0	-3.1	.211	-171.9
1850.0	48.5	-3.0	.216	-172.2
1900.0	48.0	-2.8	.221	-172.8
1950.0	47.5	-2.5	.225	-173.6
2000.0	47.1	-2.2	.229	-174.5

Figure 17. Smith Chart Normalized to 75 ohms Showing Impedance and Reflection Coefficient Data (Biased Thermistor Mount)

SMITH CHART NORMALIZED TO: 50.0				
FREQ	IMPEDANCE		REFLECTION COEF	
	REAL	IMAG	MAGN	ANGLE
1000.0	7.1	-1.3	.752	-176.9
1050.0	7.2	3.0	.749	173.1
1100.0	7.4	6.4	.747	165.0
1150.0	7.5	10.4	.740	155.9
1200.0	8.2	14.3	.738	147.3
1250.0	8.6	18.5	.737	138.4
1300.0	9.3	22.9	.736	129.6
1350.0	10.2	27.9	.732	120.1
1400.0	11.2	32.7	.732	111.8
1450.0	12.6	38.6	.731	102.4
1500.0	14.4	44.8	.730	93.6
1550.0	16.9	52.3	.729	84.3
1600.0	19.8	60.1	.731	76.0
1650.0	24.1	69.5	.730	67.2
1700.0	32.3	80.9	.730	58.5
1750.0	40.5	94.9	.727	49.4
1800.0	54.7	110.8	.727	41.0
1850.0	79.7	132.1	.731	31.8
1900.0	125.3	147.0	.722	22.9
1950.0	196.3	140.0	.715	14.1
2000.0	278.2	74.5	.713	5.3

Figure 18. Smith Chart Normalized to 50 ohms Showing Impedance and Reflection Coefficient Data (Unbiased Thermistor Mount)

terminated in the system's characteristic impedance (Z_O). The full scale value of the magnitude is displayed on the polar display. The system automatically selects a value of full scale reflection for best resolution. The frequency range (1000 to 2000 MHz) is read clockwise.

Figure 20 shows the same 3-dB attenuator without a termination (open circuit). This is illustrated to show the automatic range-changing capability of the system. The change in the position of the dots is caused by the change in reflection coefficient at the measurement port as seen by the system.

Teletype Printout

Figure 21 shows the printouts obtained by terminating the attenuator with the system's characteristic impedance. The additional information of VSWR and return loss in dB is also printed.

MEASUREMENT OF A LOW-PASS FILTER

MEASUREMENT PROGRAM USED: TRAN2

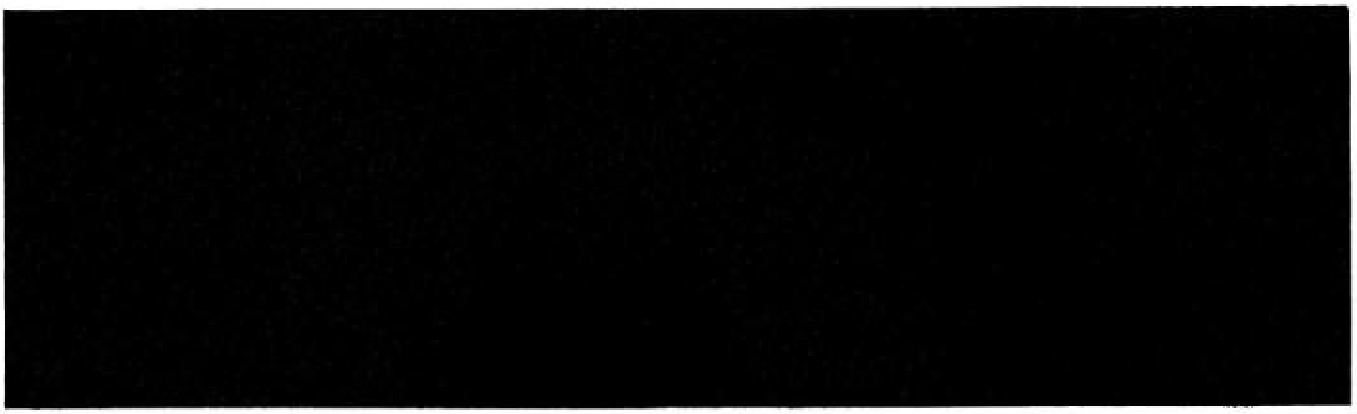
MEASUREMENT DATA OBTAINED:

Oscilloscope Displays

Insertion Loss/Gain in dB

Phase Shift in Degrees

Group Delay in Nanoseconds



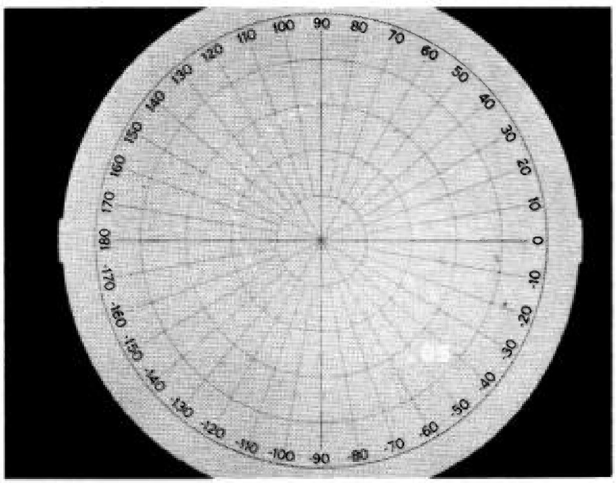


Figure 19. Reflection Coefficient of Attenuator (Terminated with Z_o)

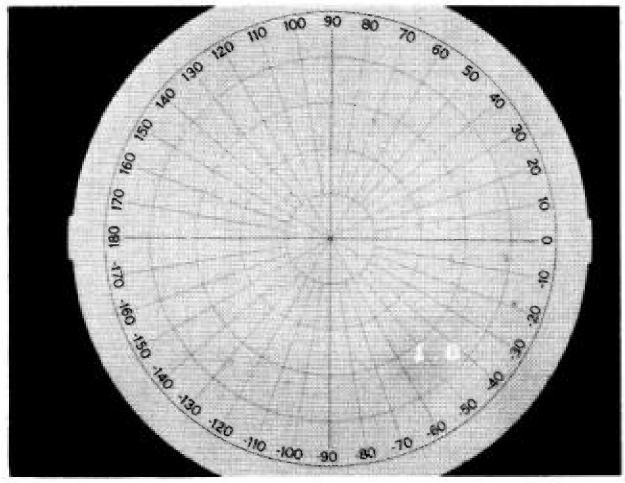
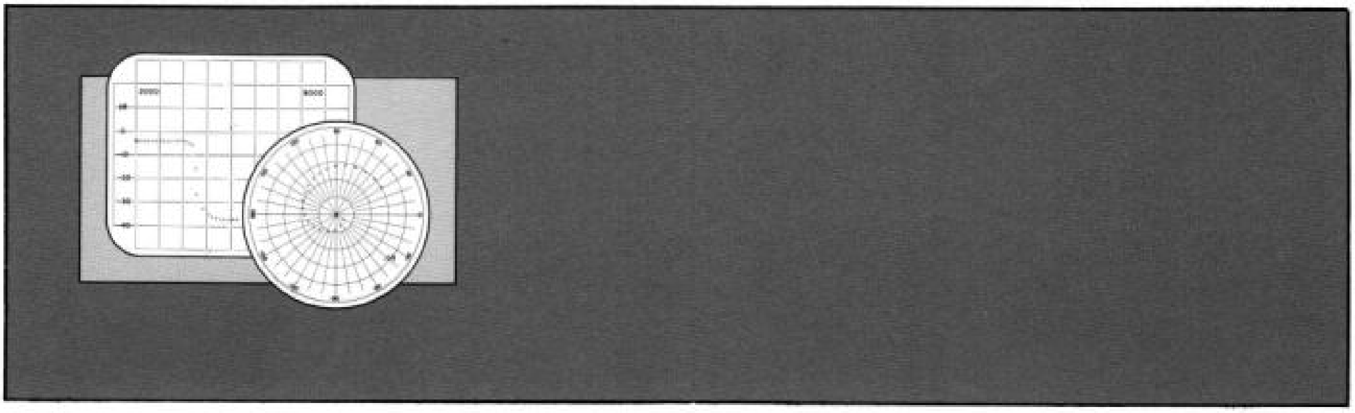


Figure 20. Reflection Coefficient of Attenuator (not Terminated)

FREQ	REFL: MAGN	ANGLE	VSWR	RTN LOSS
1000.0	.015	-156.5	1.031	36.26
1050.0	.016	-164.5	1.033	35.89
1100.0	.017	-171.2	1.034	35.56
1150.0	.018	-177.4	1.036	35.14
1200.0	.018	176.1	1.037	34.85
1250.0	.019	169.5	1.038	34.51
1300.0	.019	163.4	1.040	34.25
1350.0	.020	157.6	1.041	33.99
1400.0	.021	152.0	1.042	33.72
1450.0	.022	145.5	1.044	33.34
1500.0	.022	140.2	1.046	32.98
1550.0	.023	135.2	1.048	32.63
1600.0	.024	129.6	1.049	32.35
1650.0	.025	124.2	1.051	32.06
1700.0	.026	118.8	1.053	31.75
1750.0	.027	113.1	1.056	31.29
1800.0	.028	107.9	1.058	31.04
1850.0	.029	102.3	1.060	30.77
1900.0	.030	97.4	1.061	30.56
1950.0	.031	91.5	1.063	30.28
2000.0	.032	87.1	1.065	29.99

Figure 21. Teletype Printout of Reflection Coefficient Data Characterizing a 3-dB Attenuator



Teletype Printout

Insertion Loss/Gain in dB

Phase Shift in Degrees

TYPE OF MEASUREMENT: Transmission

MEASUREMENT RESULTS: The program begins by calibrating the system. First, the frequency range is asked for with the frequency intervals in MHz.

FREQ START, STOP, STEP (MHZ)?

Next, the system uses a standard load to determine the isolation between the reference and test channels of the network analyzer subsystem. The system stores this data in its memory for later correction of data obtained from a test device. Then, the two ports of the transmission/reflection unit are connected together and the tracking of both channels is measured. This data is also stored in the system's memory. The system is now calibrated.

The test device is then inserted in the system. For demonstration purposes, a low-pass filter with a cut-off frequency (F_c) of 1200 MHz is connected between the two ports of the transmission/reflection test unit.

Oscilloscope Display

Group Delay

Figure 22 shows the group delay of signals through the filter. The horizontal axis represents frequency, (1000 to 2000 MHz) and the vertical axis shows the group delay in nanoseconds. The peak near 1200 MHz where the filter begins to roll off is typical.

Group delay data is not highly valid at insertion losses below -80 dB because of noise at these low levels and also because of the rapidly changing phase shift of the low-pass filter used in this example. (Note the difference between Figure 25 and 26 and the data printout of Figure 27.) Averaging of data would have provided greater agreement of values between the oscilloscope and teletype outputs.

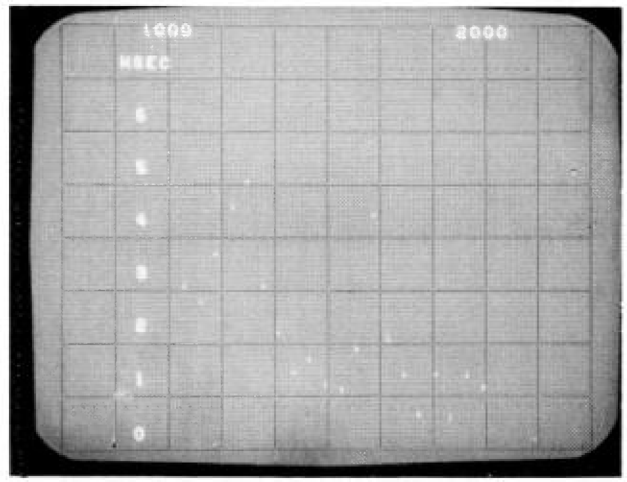


Figure 22. Group Delay (Nanoseconds)

Insertion Loss/Gain

Figure 2 shows the loss in the dB of the filter with frequency again plotted on the horizontal axis and dB being plotted on the vertical axis. The zero dB line is also plotted.

Figure 24 is the same display as shown in Figure 23 except the 0 dB line is removed to facilitate reading of data near the 0 dB line.

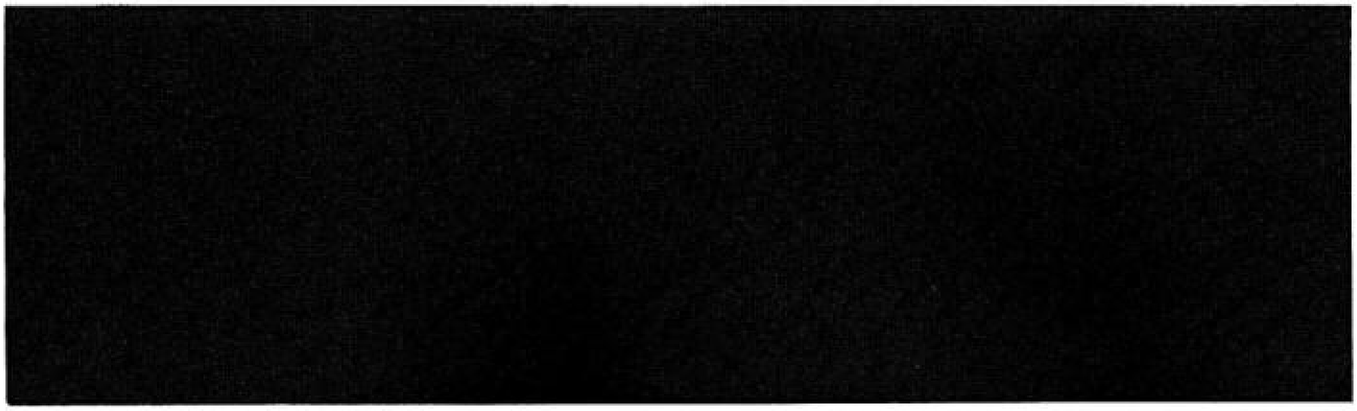
Insertion Loss/Gain, Phase Shift

Three descrete frequencies in the passband of the filter are shown in Figure 25.

Figure 26 shows three descrete frequencies out of the passband.

Teletype Printout

Figure 27 is an example of a teletype printout of the filter.



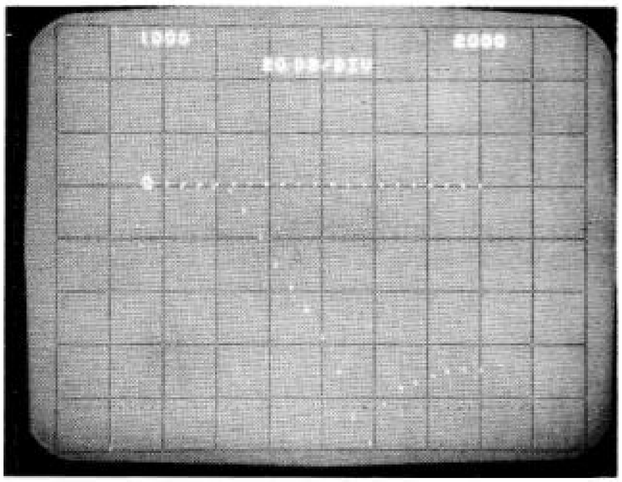


Figure 23. Insertion Loss (dB) with Zero Line

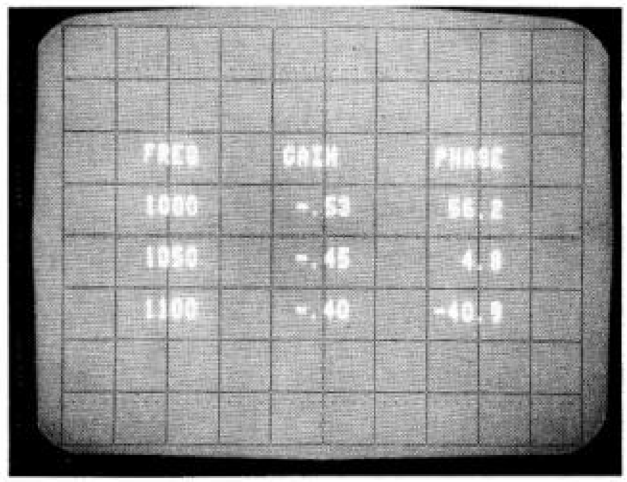


Figure 25. Gain (dB) /Phase (Degrees)

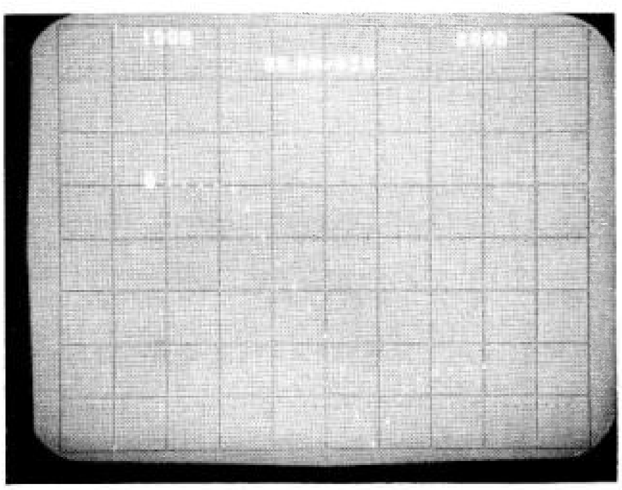


Figure 24. Insertion Loss (dB) without Zero Line

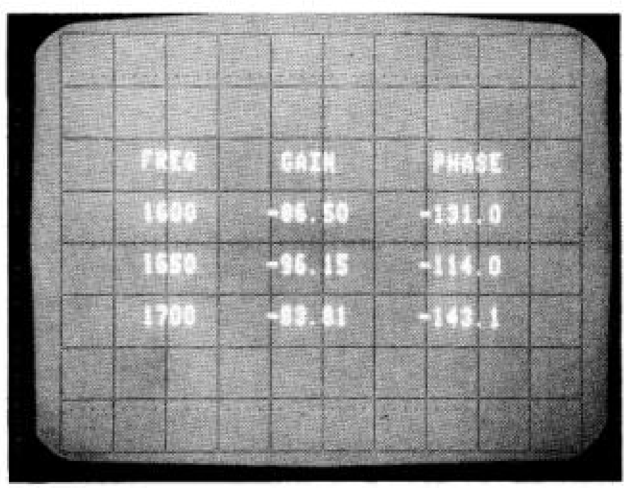
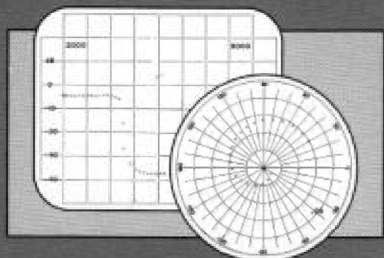


Figure 26. Gain (dB) /Phase (Degrees)



TRANSMISSION MEASUREMENT

FREQ	GAIN	PHASE
1000.	-.54	56.3
1050.	-.45	4.8
1100.	-.40	-40.9
1150.	-.58	-104.6
1200.	-1.59	173.9
1250.	-10.06	66.8
1300.	-20.77	36.3
1350.	-31.29	.6
1400.	-39.24	-22.6
1450.	-48.57	-47.7
1500.	-58.93	-69.5
1550.	-71.66	-91.4
1600.	-86.51	-131.1
1650.	-96.15	-114.1
1700.	-83.81	-143.2
1750.	-73.26	-171.9
1800.	-74.61	173.7
1850.	-73.38	151.2
1900.	-70.93	131.7
1950.	-69.22	116.5
2000.	-65.48	101.3

Figure 27. Attenuation in dB and Phase Shift through a Low-Pass Filter

MEASUREMENT OF A 10-dB ATTENUATOR

MEASUREMENT PROGRAM USED: TRAN3

MEASUREMENT DATA OBTAINED:

Oscilloscope Displays

Insertion Loss/Gain in dB

Total Phase Shift in Degrees

Deviation from Linear Insertion Gain/Loss in dB

Deviation from Linear Phase Shift in Degrees

Group Delay in Nanoseconds

Teletype Printout

Insertion Loss/Gain in dB

Total Phase Shift in Degrees

Deviation from Linear Insertion Gain/Loss in dB

Deviation from Linear Phase Shift in Degrees

Group Delay in Nanoseconds

TYPE OF MEASUREMENT: Transmission

MEASUREMENT RESULTS: The program begins by calibrating the system. First, the frequency range is asked for with the frequency intervals in MHz.

FREQ START, STOP, STEP (MHZ)?

Next, the system uses standard loads to determine the isolation between the test and reference channels of the network analyzer system. The system stores this data in its memory for later correction of data obtained from a test device (a 10-dB attenuator).

Then, the two ports of the transmission/reflection unit are connected together and the tracking of both channels is measured. The system is then calibrated.

The 10-dB attenuator is now inserted into the system. The teletype will then respond with the electrical length of the device in cm.

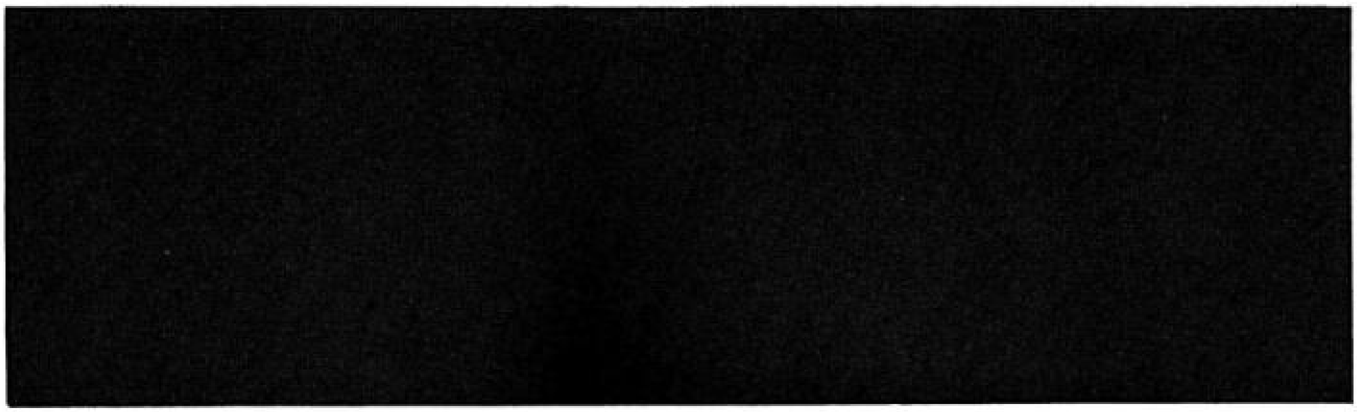
ELEC LNG = 7.33 CM

Oscilloscope Display

Insertion Loss/Gain

Figure 28 shows the insertion loss of the attenuator over the 1000 to 2000 MHz frequency range. The numbers in the bottom portion of the display, from left to right are the task numbers (an arbitrary code number to identify the insertion loss plot), base line value (value of bottom graticule line), and graticule division values (scale). In Figure 28, the program is operating in task 4, with a -13 dB base line with 1 dB per division increments. Figure 29 shows an expanded display of the insertion loss over the 1200 to 1600 MHz frequency range with a -10.2 dB base line and .1 dB per division.

Figure 30 shows the insertion loss over 1300 to 1400 MHz when the base line is set to -10.2 dB and each division is .1 dB.



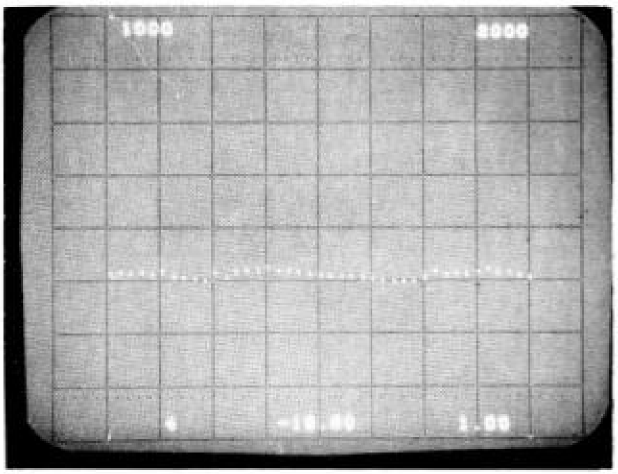


Figure 28. Insertion Loss (dB)

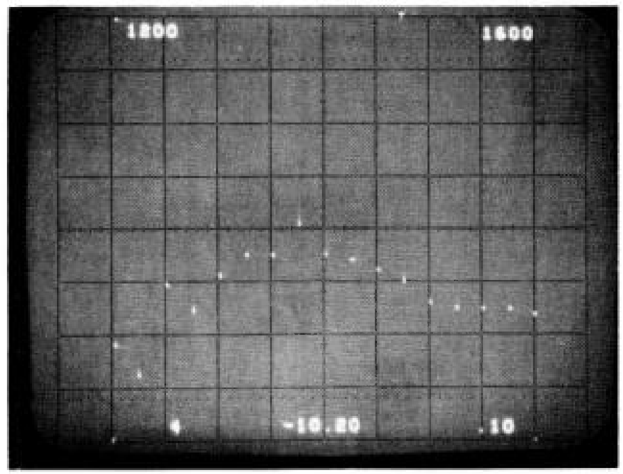


Figure 29. Insertion Loss (dB), Narrow Band, Increased Resolution

Total Phase Shift

Figure 31 shows the total phase shift of the attenuator over its frequency range. In this example, the program is operating in task 5 with a base line of -200 degrees with 20 degrees per division increments.

Deviation from Linear Gain/Loss

Figure 32 shows the deviation from linear gain/loss of the attenuator including the zero line. The bottom graticule line is -4 dB and each division is 1 dB. Figure 33 shows the same information without the zero line

Deviation from Linear Phase Shift

Figure 34 shows the deviation from linear phase shift of the attenuator. The bottom graticule line is -4 degrees and each division is 1 degree.

Group Delay

Figure 35 shows the group delay of the attenuator in nanoseconds. The bottom graticule line is -4 nanoseconds and each division is 1 nanosecond.

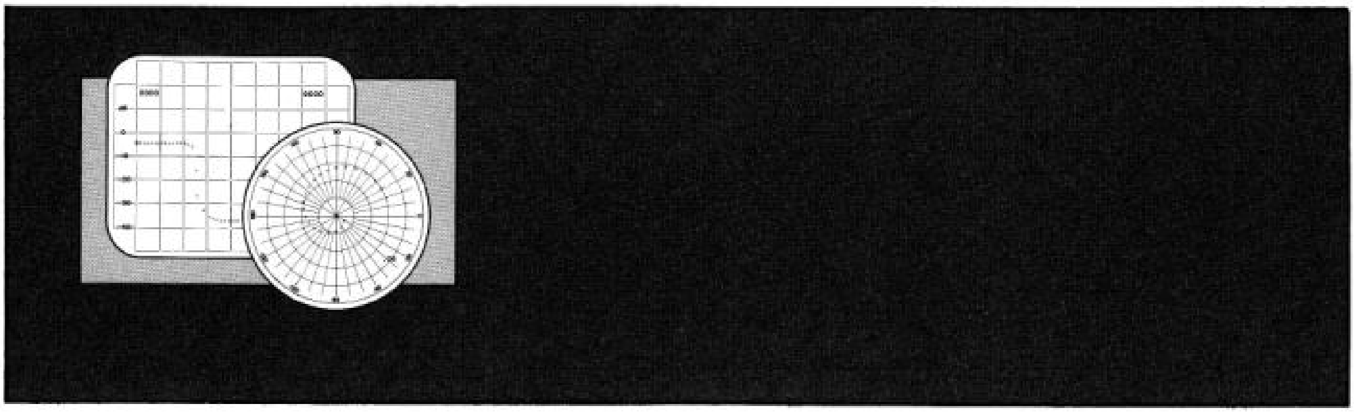
Figure 36 shows the same display as Figure 35 except the zero base line is removed.

In Figure 37, the scale has been changed so that the base line is -1 nanosecond with .25 nanosecond per division as increments.

Teletype Printouts

Figure 38 displays all the printouts that were obtained on the oscilloscope displays of the 10-dB attenuator.

Figure 39 shows the results of specifying a nominal value (10 dB) and deviation (tolerance) of ±.15 dB. Only those values exceeding the specification were therefore printed.



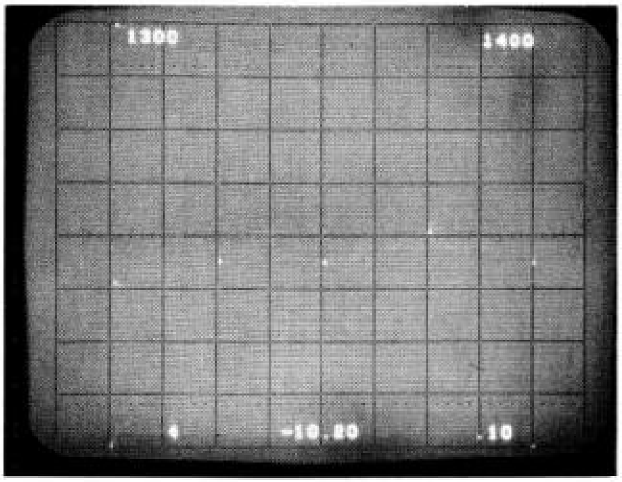


Figure 30. Insertion Loss (dB), Narrow Band, Increased Resolution

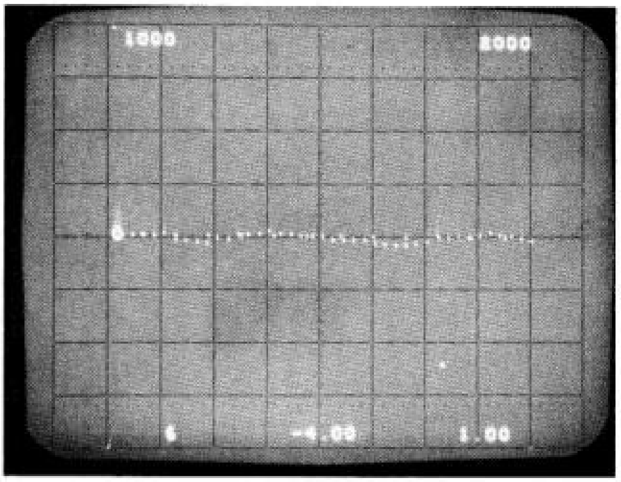


Figure 32. Deviation from Linear Gain/Loss (dB) with Zero Line

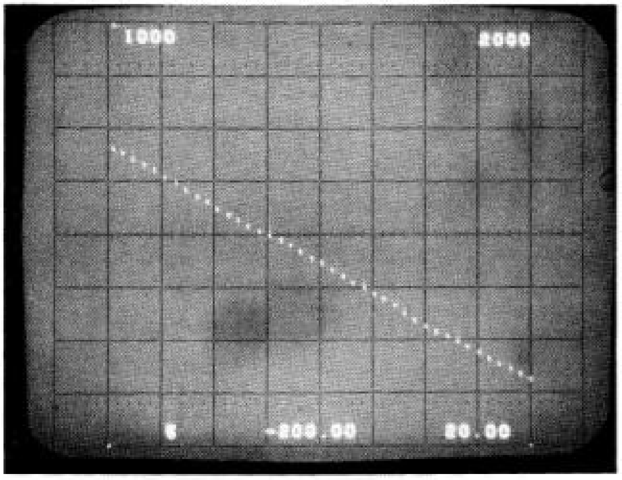


Figure 31. Total Phase Shift (Degrees)

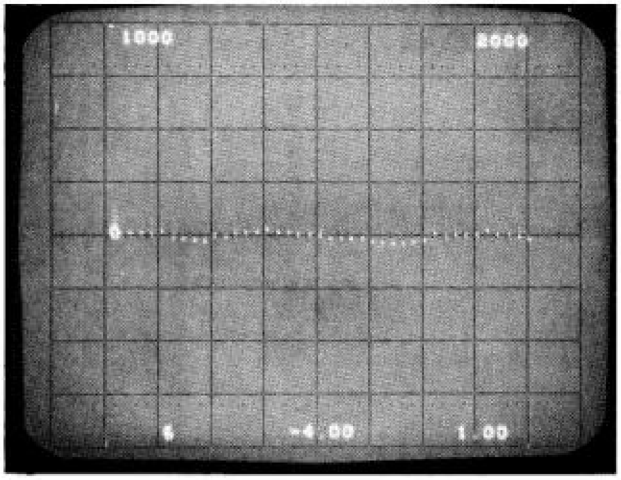
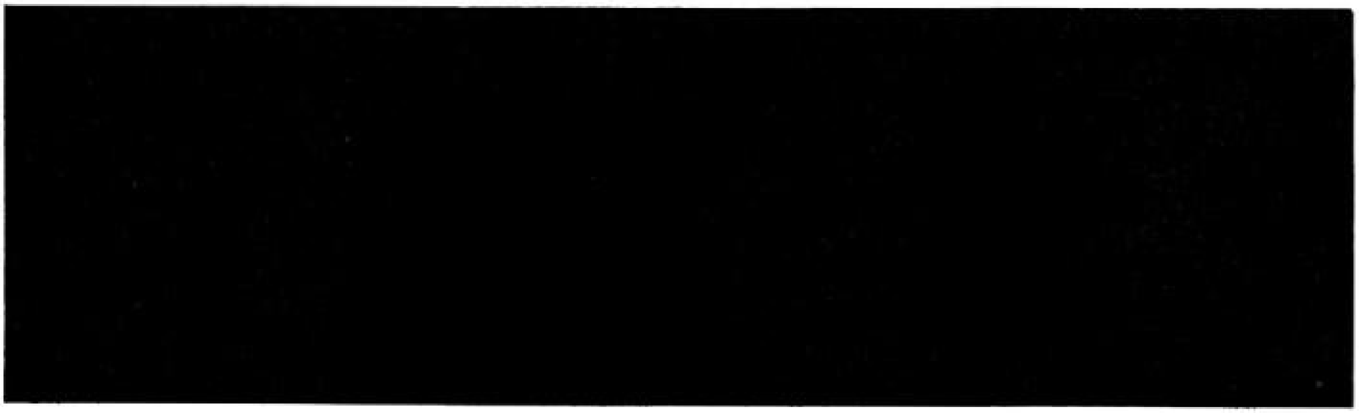


Figure 33. Deviation from Linear Gain/Loss (dB) without Zero Line



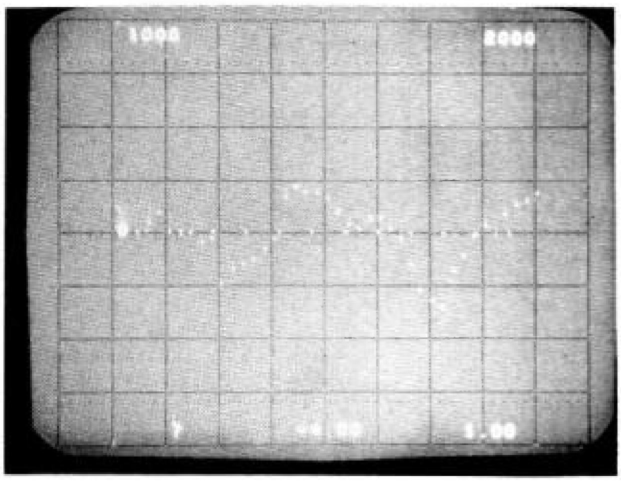


Figure 34. Deviation from Linear Phase (Degrees)

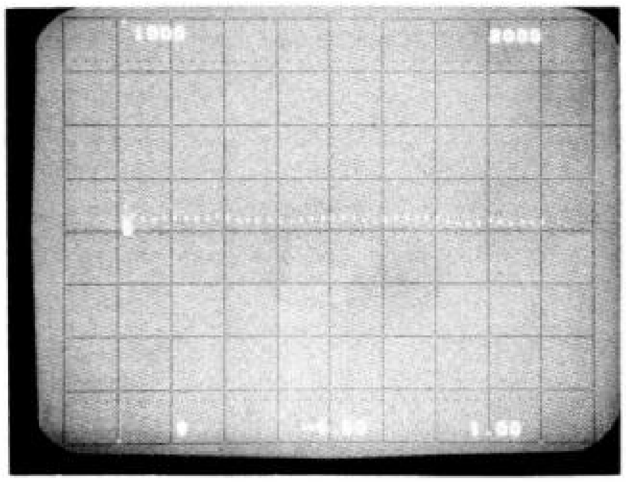


Figure 36. Group Delay (Nanoseconds) without Zero Line

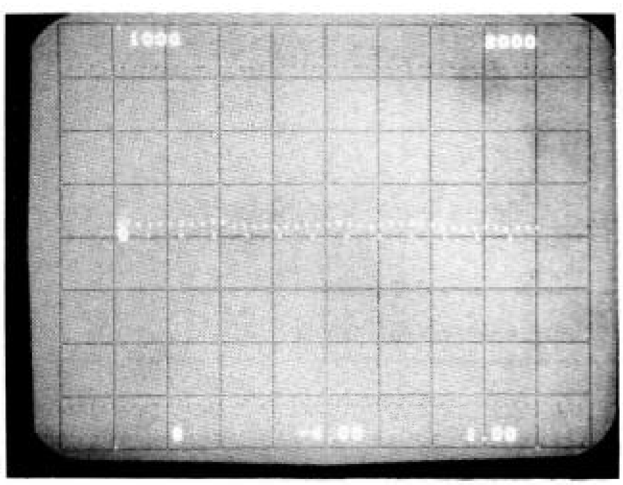


Figure 35. Group Delay (Nanoseconds) with Zero Line

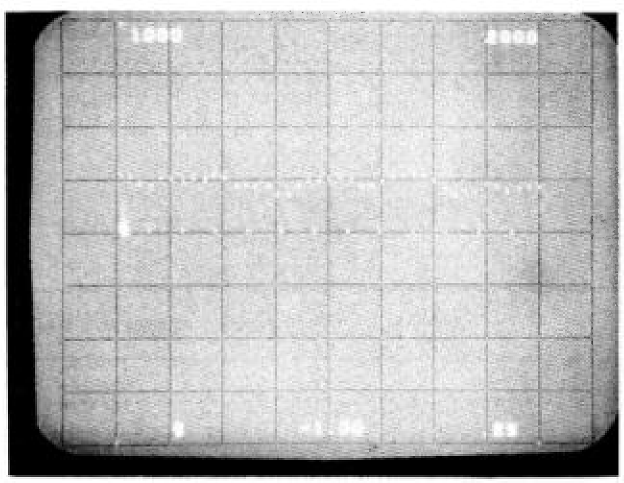
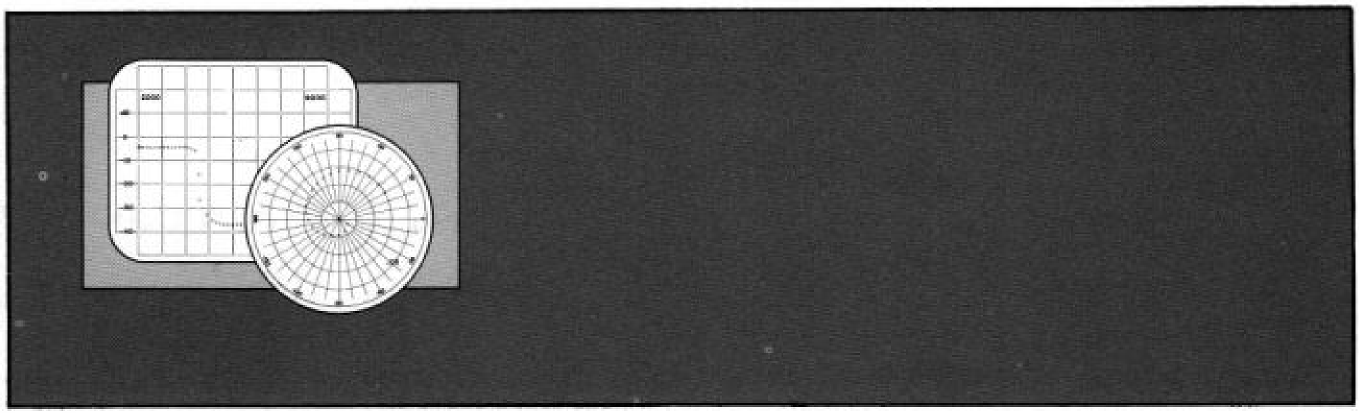


Figure 37. Group Delay (Nanoseconds) Increased Resolution



FREQ	GAIN	PHASE	DB DEV	PHS DEV	GP DLY
1000	-9.91	-86.8	.03	.6	.29
1025	-9.91	-89.5	.03	.1	.27
1050	-9.91	-91.9	.03	-.3	.23
1075	-9.91	-93.9	.02	.2	.22
1100	-9.93	-95.8	.00	.4	.26
1125	-9.87	-98.6	.06	-.1	.26
1150	-9.99	-100.6	-.06	.0	.24
1175	-9.99	-103.0	-.06	-.8	.26
1200	-10.02	-105.4	-.09	-.2	.25
1225	-10.08	-107.5	-.15	-.1	.25
1250	-9.91	-110.6	.02	-1.0	.27
1275	-9.96	-112.5	-.03	-.7	.22
1300	-9.89	-114.6	.04	-.7	.23
1325	-9.85	-116.8	.08	-.6	.22
1350	-9.85	-118.7	.08	-.4	.22
1375	-9.79	-120.7	.14	-.2	.18
1400	-9.85	-122.1	.07	.7	.18
1425	-9.86	-124.1	.05	1.0	.23
1450	-9.88	-126.3	.04	.9	.25
1475	-9.90	-128.5	.02	.9	.25
1500	-9.94	-130.9	-.02	.8	.26
1525	-9.95	-133.3	-.03	.5	.27
1550	-9.95	-135.8	-.03	.2	.26
1575	-9.95	-138.1	-.03	.1	.23
1600	-9.96	-140.2	-.04	.3	.23
1625	-10.00	-142.4	-.08	.3	.25
1650	-10.03	-144.8	-.11	.1	.27
1675	-10.03	-147.3	-.11	-.1	.28
1700	-10.04	-150.0	-.12	-.6	.29
1725	-10.02	-152.6	-.10	-1.1	.28
1750	-9.97	-155.0	-.06	-1.3	.26
1775	-9.84	-157.3	.07	-1.4	.21
1800	-9.90	-158.9	.01	-.8	.19
1825	-9.89	-160.8	.02	-.5	.20
1850	-9.89	-162.6	.02	-.1	.20
1875	-9.85	-164.5	.06	.2	.24
1900	-9.78	-167.1	.13	-.1	.23
1925	-9.85	-168.7	.06	.5	.20
1950	-9.85	-170.7	.06	.7	.22
1975	-9.90	-172.8	.01	.8	.23
2000	-9.95	-174.9	-.04	.9	.23

Figure 39. Teletype Printout Characterizing a 10-dB Attenuator

NOM AND DEV(DB)? -10.0, .15

FREQ	GAIN	PHASE
1375	-9.79	-120.7
1775	-9.84	-157.3
1900	-9.78	-167.1

Figure 39. Teletype Printout Characterizing a 10-dB Attenuator with Deviation from Nominal Specified

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