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ZERO LENGTH INTRASTATION FIBER OPTICS LINKS TEST & EVALUATION PROGRAM

FINAL REPORT

MAY 1981

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ZERO LENGTH INTRASTATION FIBER OPTICS LINKS

TEST AND EVALUATION PROGRAM

FINAL REPORT

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SUMMARY

This program covers the test and evaluation of then available selected commercial fiber optic (F/O) transmission systems used as interconnect links in a typified Defense Communications Systems (DCS) transmission node between DCS digital multiplexers and radios. The intent being to evaluate fiber optics utility as interconnect links in a typical DCS Intrastation environment (less than 300 feet) and to evaluate their performance against equivalent conventional metallic interconnects. Results indicate that F/O systems are as equally suitable for intrastation applications as the equivalent metallic wire/cable systems and do have some advantages as high data rate interconnects.

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ZERO LENGTH FIBER OPTICS LINKS TEST AND EVALUATION PROGRAM

1. PROGRAM OBJECTIVE

The objective of this program is to evaluate currently available commercial fiber optic systems to determine their potential for zero-length intra-station (less than 300 feet) applications in the Defense Communications Systems (DCS), and where appropriate, to make recommendations for general design criteria that may be utilized in DCS performance specifications and standards

2. SCOPE

a. The test and evaluation of the three commercial fiber optics systems and their metallic cable counterparts was conducted by US Army Electronics Proving Ground (USAEPG) personnel from 1 October 1979 to 28 March 1980 under the technical direction of the US Army Communication Electronics Engineering Installation Agency (USACEEIA). Supplemental testing was conducted from 23 May to 20 June 1980 by the same personnel. With the exception of TEMPEST testing, all tests were conducted at the USAEPG Communications Test Facility (CTF) at Fort Huachuca, Arizona by military technicians of military occupational specialty (MOS) 32D and 26V. US Army Communications Systems Agency was overall project manager for this test and evaluation project.

b. Testing at the CTF included an evaluation of the crosstalk, idle channel noise, distortion, frequency response, data error rate, installation and recovery time, and the durability characteristics of the three fiber optic systems. Twenty-six pair and coaxial metallic cable systems were also tested in order to provide a direct comparison with equivalent fiber optic systems.

c. TEMPEST testing was conducted between 15 February and 15 March 1980 at the USAFPG EMI test facility at Fort Huachuca. Classified results are not discussed in this report, but are available on a need to know basis from Commander, US Army Communications-Electronics Command, DRSEL-COM-RM-1, Fort Monmouth, NJ 07703.

3. SUMMARY OF TEST RESULTS

The following is a summary of the test results. Complete test procedure, test setups, and results can be found in appendix A, Initial Testing and Test Results. Supplemental Testing and Test Results can be found in appendix B.

4. DESCRIPTION OF MATERIEL

a. The performance of three fiber optic systems was evaluated. The systems included the following modems and fiber optic cable:

(1) 4 kHz Voice Link

(a) Manufacturer A (CECOM Government Furnished Equipment (GFE) Fiber Optic Modem (full duplex, voice, 13 channels). Four (4), four (4) and five (5) 4 kHz voice channels multiplexed and combined for one-way transmission on each of three (3) fibers, respectively; using an optical modulator.

(b) Manufacturer A (CECOM GFE) Fiber Optic Cable (100 meter lengths)

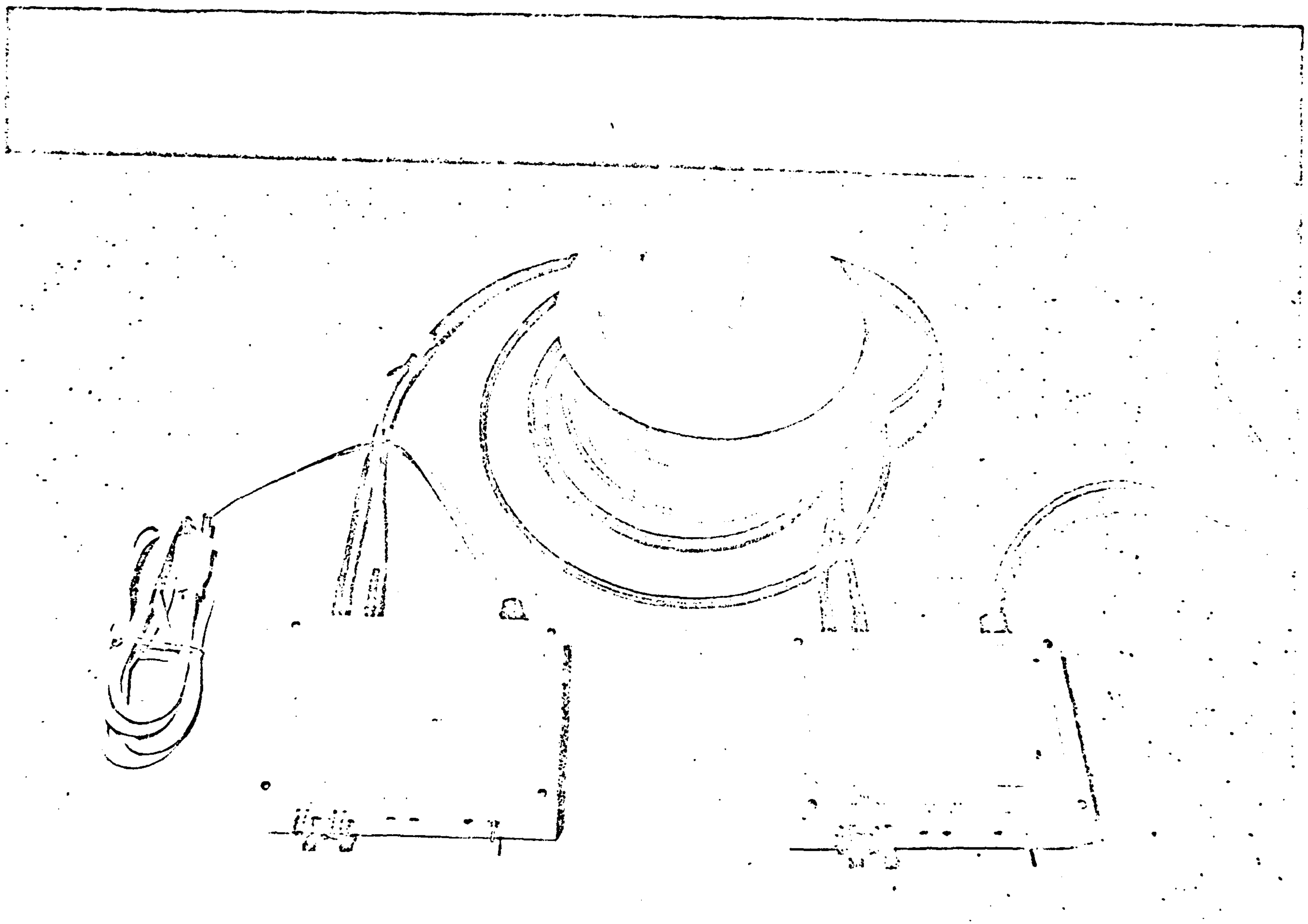

Figure 1. 1.544 MB/S Fiber Optic Data Link

(2) 1.544 Mbs Data Link (Figure 1)

(a) Manufacturer B TTL Fiber Optic Data Link, Model TTK-D1

(b) Manufacturer B Heavy Duty Fiber Optic Cable, Model HT-PC10-02 (10 and 100 meter lengths)

(3) 12.6 Mbs Data Link

(a) Manufacturer C Fiber Optic Modem (20 MHz analog) Model T-608 (Figure 2)

(b) Manufacturer C Fiber Optic Modem (20 MHz analog) Model T-603

(c) Manufacturer C Fiber Optic Cable, Model T-432 (10 and 100 meter lengths)

b. The performance of two metallic cable links was evaluated in order to provide a basis of comparison with the fiber optic links. The metallic cables tested were:

(1) 4 kHz voice link - 26 pair cable (250 feet long)

(2) 1.544 and 12.6 Mbs data links - RG-59B/U coaxial cable (MIL-C-17D)

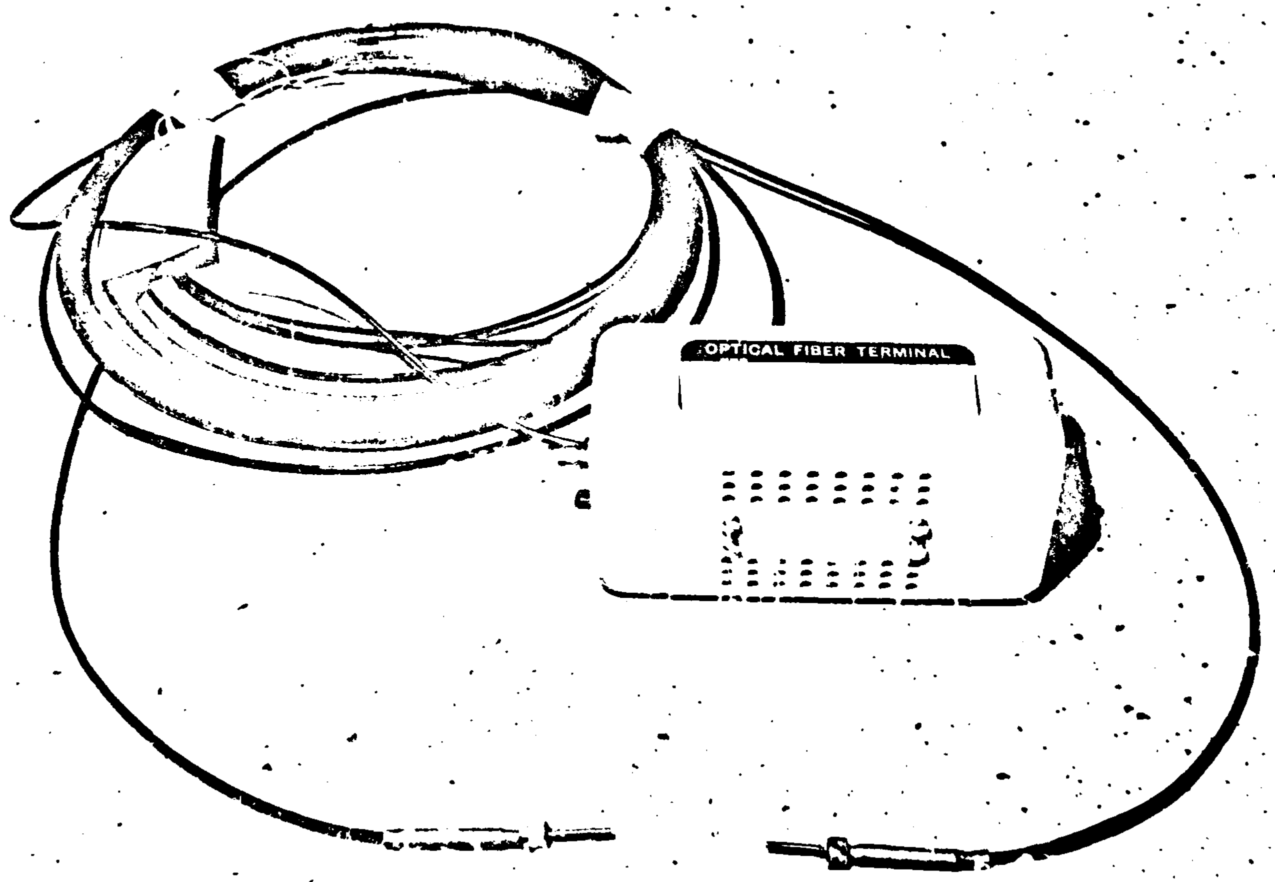

Figure 2. 12.6 MB/S Fiber Optic Data Transmitter

5. TEST DATA

a. 4-kHz Voice Link

(1) Idle Channel Noise (ICN)

(a) Manufacturer A fiber optic system. Results are shown in table I for a 100 meter length of fiber optic cable and the two modems. Note that only channels 9 - 12 were operational in the system.

TABLE I. IDLE CHANNEL NOISE OF 4-kHz FIBER OPTIC SYSTEM

Channel No.	Idle Channel Noise (dBrnc)
9	24
10	28
11	25
12	24

(b) 26 pair metallic cable (250 feet). The ICN for each pair of the cable was less than or equal to -5 dBrnc.

NOTE: 0 dBrnc = -90dBm C message weighing at 1000 Hz

(2) Crosstalk

(a) Manufacturer A fiber optic system. Results are shown in table II for the 100 meter length of fiber optic cable and the two modems. Fiber optic cables are multi-mode graded index fibers, full duplex plus timing. Cross talk results from the modems not the fiber linkages.

TABLE II. CROSSTALK OF 4-kHz FIBER OPTIC SYSTEM

Channel Tested (No.)	Idle Channel Noise of Channel Tested (dBrnc)	Crosstalk Measurement (dBrnc) 1000 Hz -10 dBm Tone on Channel 9	1000 Hz -10 dBm Tone on Channel 10	1000 Hz -10 dBm Tone on Channel 11	1000 Hz -10 dBm Tone on Channel 12
9	24	—	29	27	26
10	28	29	—	29	29
11	25	26	27	—	30
12	24	27	25	26	—

(b) 26 pair cable. Pair No. 15 was found to be defective. The crosstalk level was less than or equal to -5dBrnc for the remaining 25 pairs.

(3) Distortion. Percent distortion at input frequencies of 1, 2, and 3 kHz is shown in table III for both the fiber optic system and the 26 pair cable.

TABLE III. 4-kHz VOICE DISTORTION

Frequency of -10 dBm Test Tone (Hz)	Baseline measurement	Distortion Levels (%)							
		Fiber Optic System				Metallic Cable System			
		Chan 9	Chan 10	Chan 11	Chan 12	Pair 1	Pair 13	Pair 14	Pair 26
1000	0.072	1.2	0.7	1.25	1.95	0.072	0.072	0.072	0.072
2000	0.046	1.0	0.7	1.15	1.85	0.048	0.048	0.048	0.048
3000	0.038	0.95	0.8	1.2	1.75	0.040	0.040	0.040	0.040

(4) Frequency Response

(a) Measurements were made for the Manufacturer A fiber optic system with 100 meters of fiber optic cable as a supplemental test.

(b) The frequency response of channel 9 of the system, with XMIT modem SN 001 and RCVR modem SN 002, is shown in table IV and figure 1. The absolute output level at 1 kHz was -11.7 dBm.

(c) The frequency response of channel 9 of the system, with XMIT modem SN 002 and RCVR modem SN 001, is shown in table V and figure 1. The absolute output level at 1 kHz was -10.5 dBm.

(d) The frequency response of channel 9 of the system, with XMIT modem SN 001 and RCVR modem SN 002, is shown in table VI and figure 2. The absolute output level at 1 kHz was -13.5 dBm.

(e) The frequency response of channel 11 of the system, with XMIT modem SN 002 and RCVR modem SN 001, is shown in table VII and figure 2. The absolute output level at 1 kHz was -10.7 dBm.

(f) During testing, it was noted that the cable for the optical connection between the modems did not seat well. Movement was capable of changing output by up to 6 dB.

TABLE IV. FREQUENCY RESPONSE OF CHANNEL 9 OF 4-kHz FIBER OPTIC SYSTEM WITH XMIT MODEM SN 001 AND RCVR MODEM SN 002

FREQ (kHz)	LOSS (dB)	FREQ (kHz)	LOSS (dB)
0.2	0.2	2.1	3.3
0.3	0.4	2.2	3.5
0.4	1.0	2.3	3.6
0.5	1.5	2.4	3.8
0.6	1.5	2.5	3.9
0.7	2.0	2.6	4.0
0.8	2.0	2.7	4.2
0.9	2.3	2.8	4.4
1.0	1.7	2.9	4.5
1.1	1.8	3.0	4.5
1.2	1.9	3.1	4.7
1.3	2.0	3.2	5.0
1.4	2.3	3.3	5.1
1.5	2.5	3.4	5.3
1.6	3.2	3.5	5.5
1.7	2.4	3.6	5.6
1.8	2.7	3.7	6.0
1.9	3.0	3.8	6.0
2.0	3.0	3.9	6.1
		4.0	6.2

TABLE V. FREQUENCY RESPONSE OF CHANNEL 9 OF 4-kHz FIBER OPTIC SYSTEM WITH XMIT MODEM SN 002 AND RCVR MODEM SN 001

FREQ (kHz)	LOSS (dB)	FREQ (kHz)	LOSS (dB)
0.2	-2.0	2.1	2.2
0.3	-1.0	2.2	2.2
0.4	-0.5	2.3	2.4
0.5	0.0	2.4	2.5
0.6	0.0	2.5	2.7
0.7	0.2	2.6	3.0
0.8	0.3	2.7	3.1
0.9	0.3	2.8	3.3
1.0	0.5	2.9	3.5
1.1	0.8	3.0	3.6
1.2	1.0	3.1	3.8
1.3	1.0	3.2	4.0
1.4	1.2	3.3	4.1
1.5	1.3	3.4	4.3
1.6	1.5	3.5	4.4
1.7	1.5	3.6	4.6
1.8	1.7	3.7	4.7
1.9	1.8	3.8	4.9
2.0	2.0	3.9	5.0
		4.0	5.2

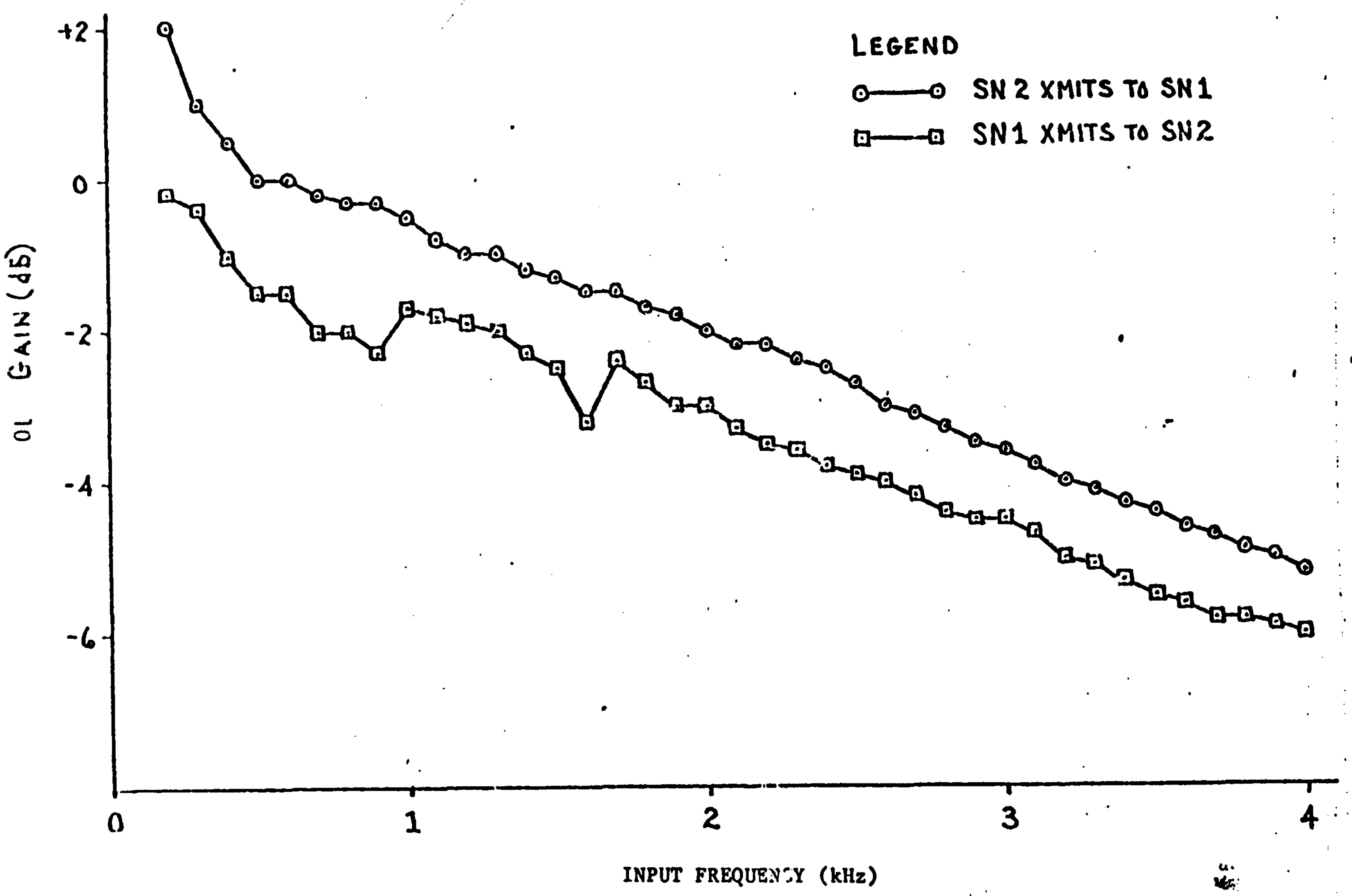

Figure 3 Frequency response of channel 9 of 4 kHz-fiber optic system

TABLE VI. FREQUENCY RESPONSE OF CHANNEL 11 OF 4-kHz FIBER OPTIC SYSTEM USING XMIT MODEM SN 001 AND RCVR MODEM SN 002

FREQ (kHz)	LOSS (dB)	FREQ (kHz)	LOSS (dB)
0.2	4.0	2.1	3.8
0.3	4.7	2.2	4.0
0.4	4.9	2.3	4.1
0.5	4.8	2.4	4.4
0.6	4.5	2.5	4.4
0.7	4.0	2.6	4.5
0.8	3.7	2.7	4.6
0.9	3.5	2.8	4.7
1.0	3.5	2.9	5.0
1.1	3.5	3.0	5.0
1.2	3.4	3.1	5.2
1.3	3.4	3.2	5.4
1.4	3.4	3.3	5.5
1.5	3.4	3.4	5.6
1.6	3.5	3.5	5.8
1.7	3.5	3.6	6.0
1.8	3.5	3.7	6.1
1.9	3.6	3.8	6.3
2.0	3.7	3.9	6.5
		4.0	6.5

TABLE VII. FREQUENCY RESPONSE OF CHANNEL 11 OF 4-kHz FIBER OPTIC SYSTEM USING XMIT MODEM SN 002 AND RCVR MODEM SN 001

FREQ (kHz)	LOSS (dB)	FREQ (kHz)	LOSS (dB)
0.2	-0.1	2.1	1.7
0.3	1.0	2.2	1.8
0.4	0.9	2.3	2.0
0.5	0.8	2.4	2.1
0.6	0.8	2.5	2.4
0.7	0.7	2.6	2.5
0.8	0.7	2.7	2.5
0.9	0.7	2.8	2.6
1.0	0.7	2.9	2.8
1.1	0.7	3.0	3.0
1.2	0.8	3.1	3.1
1.3	0.9	3.2	3.3
1.4	0.9	3.3	3.5
1.5	1.0	3.4	3.5
1.6	1.1	3.5	3.6
1.7	1.2	3.6	3.8
1.8	1.4	3.7	3.8
1.9	1.5	3.8	3.0
2.0	1.6	3.9	3.2
		4.0	3.4

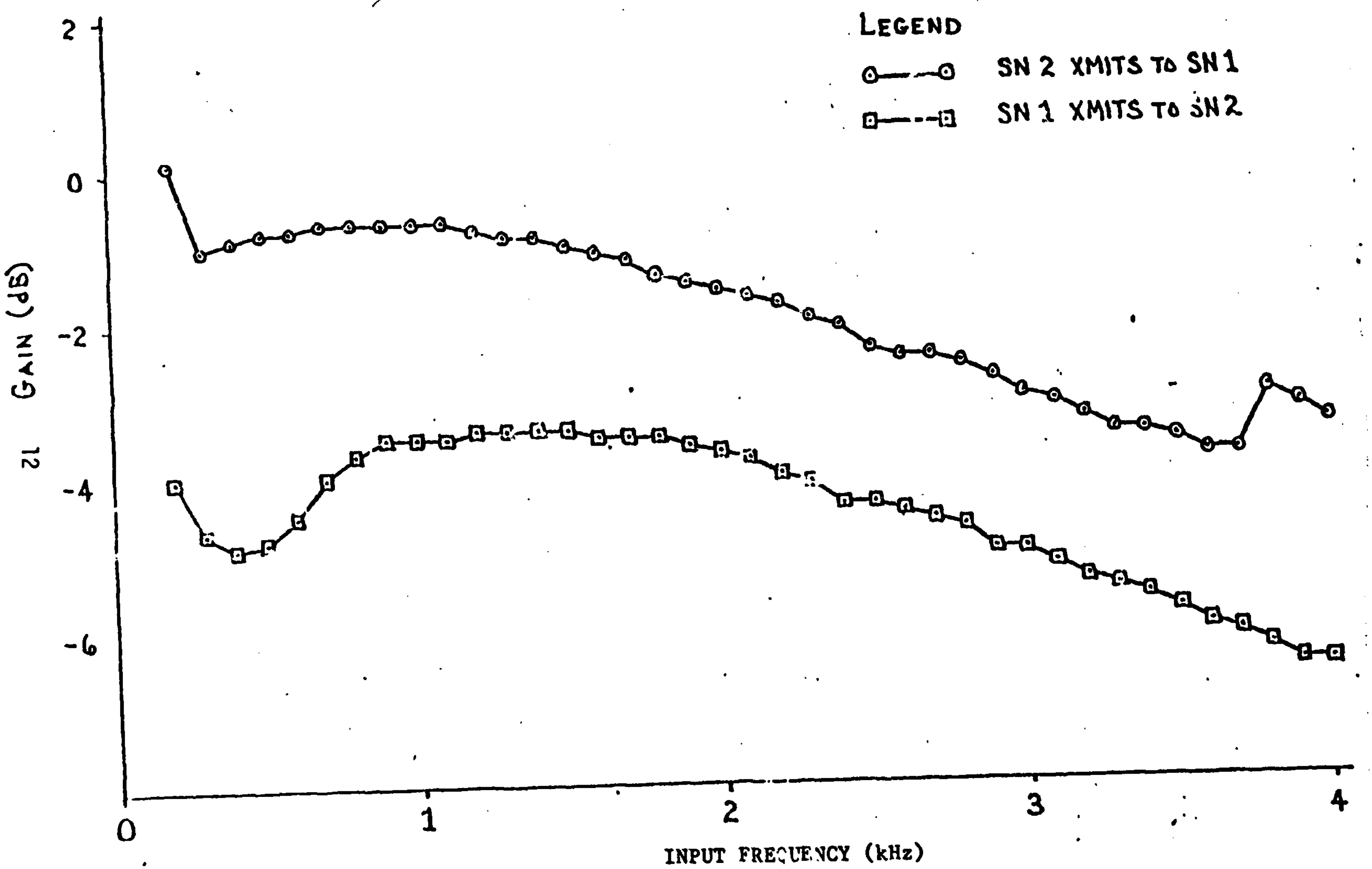

Figure 4 Frequency response of channel 11 of 4-kHz for fiber optic system.

b. 1.544 Mbs Data Link

(1) Idle Channel Noise

(a) Manufacturer B Fiber Optic System. Results are shown in table VIII for the ICN level of the modems and 10 or 100 meters of fiber optic cable.

TABLE VIII. IDLE CHANNEL NOISE OF 1.544 Mbs FIBER OPTIC SYSTEM

Channel Tested (No.)	Idle Channel Noise (dBrnc)			
	TSEC/CY-104 Looped Back	10-meter Fiber Optic Cable	TSEC/CY-104 Looped Back	100-meter Fiber Optic Cable
3	22	22	22	22
7	18	20	18	20
10	24	24	24	24
15	23	24	23	24
19	24	24	24	24
22	18	18	18	18

(b) Coaxial cable RG-59B/U. Results are shown in table IX for the ICN level of 10 or 100 meters of coaxial cable.

TABLE IX. IDLE CHANNEL NOISE OF 1.544 Mbs METALLIC CABLE SYSTEM

Channel Tested (No.)	Idle Channel Noise (dBrnc)			
	TSEC/CY-104 Looped Back	10-meter Coax Cable	TSEC/CY-104 Looped Back	100-meter Coax Cable
3	22	24	22	22
7	18	22	18	20
10	23	23	24	24
15	22	24	22	24
19	24	24	24	24
22	18	20	18	18

(2) Crosstalk

(a) Manufacturer B Fiber Optic System. Results are shown in tables X and XI.

TABLE X. CROSSTALK MEASUREMENT. 1.544 Mbs DATA LINK
(-16 dBm TONE INSERTED ON CHANNEL 2)

Channel Measured (No.)	Fiber Optic System				Metallic Cable System			
	10-meter		100-meter		10-meter		100-meter	
	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)
1	24	24	24	24	24	25	24	24
3	23	24	23	23	23	24	23	23
14	23	24	23	23	23	24	23	24
18	25	25	24	24	25	25	24	24

(b) Coaxial Cable. Results are shown in tables X and XI.

TABLE XI. CROSSTALK MEASUREMENT, 1.544 Mbs DATA LINK
(-16 dBm TONE INSERTED ON CHANNEL 23)

Channel Measured (No.)	Fiber Optic System				Metallic Cable System			
	10-meter		100-meter		10-meter		100-meter	
	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)
7	22	22	22	22	21	21	21	21
11	18	18	18	19	20	20	21	22
22	19	19	20	20	19	19	21	21
24	17	17	17	17	17	17	20	20

(3) Distortion

(a) Baseline readings of the input signal distortion in percent were made at frequencies of 1, 2, and 3 kHz. Results are shown in table XII.

TABLE XII. DISTORTION MEASUREMENT BASELINE READINGS

Test Tone Frequency (Hz)	Distortion (%)		
	1 meter	10 meters	100 meters
1000	0.072	0.072	0.072
2000	0.044	0.050	0.052
3000	0.038	0.045	0.046

(b) Percent distortion for the Manufacturer B fiber optic system and coaxial cable system are shown in table XIII.

TABLE XIII. DISTORTION MEASUREMENT (1.544 Mbs DATA LINK)

Channel (No.)	Frequency (Hz)	Distortion (%)				
			Fiber Optic System		Metallic Cable System	
		HY-12A	10 meters	100 meters	10 meters	100 meters
2	1000	1.95	1.95	1.95	1.95	1.95
	2000	1.90	1.90	1.90	1.90	2.00
	3000	2.70	2.70	2.70	2.70	2.70
23	1000	2.00	2.00	2.00	2.00	2.00
	2000	2.00	2.00	2.00	2.00	2.00
	3000	2.90	3.00	2.90	2.90	2.90

(4) Bit Error Rate (BER)

(a) Manufacturer B Fiber Optic System. No bit errors were recorded for any run with either 10- or 100-meter lengths of fiber optic cable. Since no errors were observed in 463.2 megabits of data, it can be stated that the point estimate system BER for a T-1 input is bracketed by the interval:

$$0 \leq \text{point estimate BER} \leq 2.2 \times 10^{-9} \text{ errors/bit}$$

(b) Coaxial cable

1 When 10-meter lengths of coaxial cable were used, no bit errors were recorded on any test run. Since no errors were observed in 463.2 megabits of data, it can be stated that the point estimate system BER for a T-1 input is bracketed by the interval:

$$0 \leq \text{point estimate BER} \leq 2.2 \times 10^{-9} \text{ errors/bit}$$

2 When 100-meter lengths of coaxial cable were used, bit errors were recorded during each of the three runs as follows: run No. 1, 2815 errors; run No. 2, 2729 errors; and run No. 3, 2771 errors. The respective point estimate BERs were 6.08×10^{-6}, 5.89×10^{-6}, and 5.98×10^{-6} errors/bit.

(5) Connect/Disconnect

(a) Manufacturer B Fiber Optic System. The fiber optic cable between the two modems to carry data was disconnected and reconnected 100 times. ICN was measured every 10 times. Results are shown in table XIV.

(b) Coaxial Cable. The cable between the TSEC/CY-104 and the AN/FCC-97 was disconnected and reconnected 100 times. ICN readings are shown in table XIV.

TABLE XIV. CONNECT/DISCONNECT TEST (ICN IN dBrnc OF CHANNEL 2)

Number of Connects/Disconnects	Idle Channel Noise (dBrnc)	
	Fiber Optic	Metallic
0	23	23
10	23	23
20	23	23
30	23	23
40	23	23
50	23	23
60	23	23
70	23	23
80	23	23
90	23	23
100	23	23

(6) Cycle Flexing

(a) A one volt peak-to-peak square wave at 1 MHz was inserted into a Manufacturer B modem. Optical power output at the end of 10 meters of fiber optic cable was measured following every 100 flexes (cycles) of the cable over a mandrel 2.5 times the diameter of the cable. Results are shown in table XV.

TABLE XV. CYCLIC FLEX TEST

Number of Cycles	Optical Power (uW)	Number of Cycles	Optical Power (uW)	Number of Cycles	Optical Power (uW)	Number of Cycles	Optical Power (uW)
0	12	600	11	1100	11	1600	10
100	12	700	11	1200	11	1700	10
200	12	800	11	1300	11	1800	10
300	12	900	11	1400	11	1900	10
400	11	1000	11	1500	11	2000	10
500	11						

(b) The optical power meter used in this test had not been calibrated. It was compared to a calibrated AG&G, Electro-Optic Division Radiometer/Photometer, Model 550-1, SN 3274. When the optical power meter read 17 microwatts, the calibrated radiometer/photometer read 14 microwatts.

(7) Installation/Recovery Time. Results for the Manufacturer B fiber optic system and coaxial (metallic) cable system are shown in table XVI for installation and table XVII for recovery.

TABLE XVI. INSTALLATION TIME

Trial Number	Installation Time (Minutes)					
	10 meters			100 meters		
	1 Person	2 Persons	3 Persons	1 Person	2 Persons	3 Persons
	Fiber Optic System					
1	5	3	3	18	6	5
2	4	3	5	17	11	5
3	4	4	3	17	11	6
4	4	3	--	12	11	--
5	4	3	--	8	10	--
6	4	3	--	10	12	--
	Metallic Cable System					
1	4	2	2	7	5	5
2	5	3	3	3	4	5
3	4	5	2	4	10	4
4	[illegible]	3	--	3	4	--
5	5	3	--	4	5	--
6	4	2	--	5	5	--

TABLE XVII. RECOVERY TIME

Trial Number	Recovery Time (Minutes)					
	10 meters			100 meters		
	1 Person	2 Persons	3 Persons	1 Person	2 Persons	3 Persons
	Fiber Optic System					
1	3	3	2	16	7	6
2	3	2	2	12	10	5
3	3	2	3	10	10	5
4	3	2	--	10	9	--
5	2	2	--	11	10	--
6	2	2	--	10	10	--
	Metallic Cable System					
1	2	1.5	2	3	5	4
2	3	2	2	11	5	3
3	3	2	1.5	11	4	4
4	5	1.5	--	6	3	--
5	2	2	--	5	4	--
6	2	1.5	--	5	3	--

(Figure 5)

c. 12.6 Mbs Data Link

(1) Idle Channel Noise

(a) Manufacturer C Fiber Optic System. Results are shown in table XVIII for the ICN level of the modems and 10 or 100 meters of fiber optic cable.

TABLE XVIII. IDLE CHANNEL NOISE OF 12.6 Mbs FIBER OPTIC SYSTEM

Channel Tested (No.)	Idle Channel Noise (dBrnc)			
	TSEC/CY-104 Looped Back	10-meter Fiber Optic Cable	TSEC/CY-104 Looped Back	100-meter Fiber Optic Cable
3	22	23	23	24
7	18	20	18	20
10	23	23	22	23
15	23	23	23	24
19	23	24	23	24
22	18	19	18	20

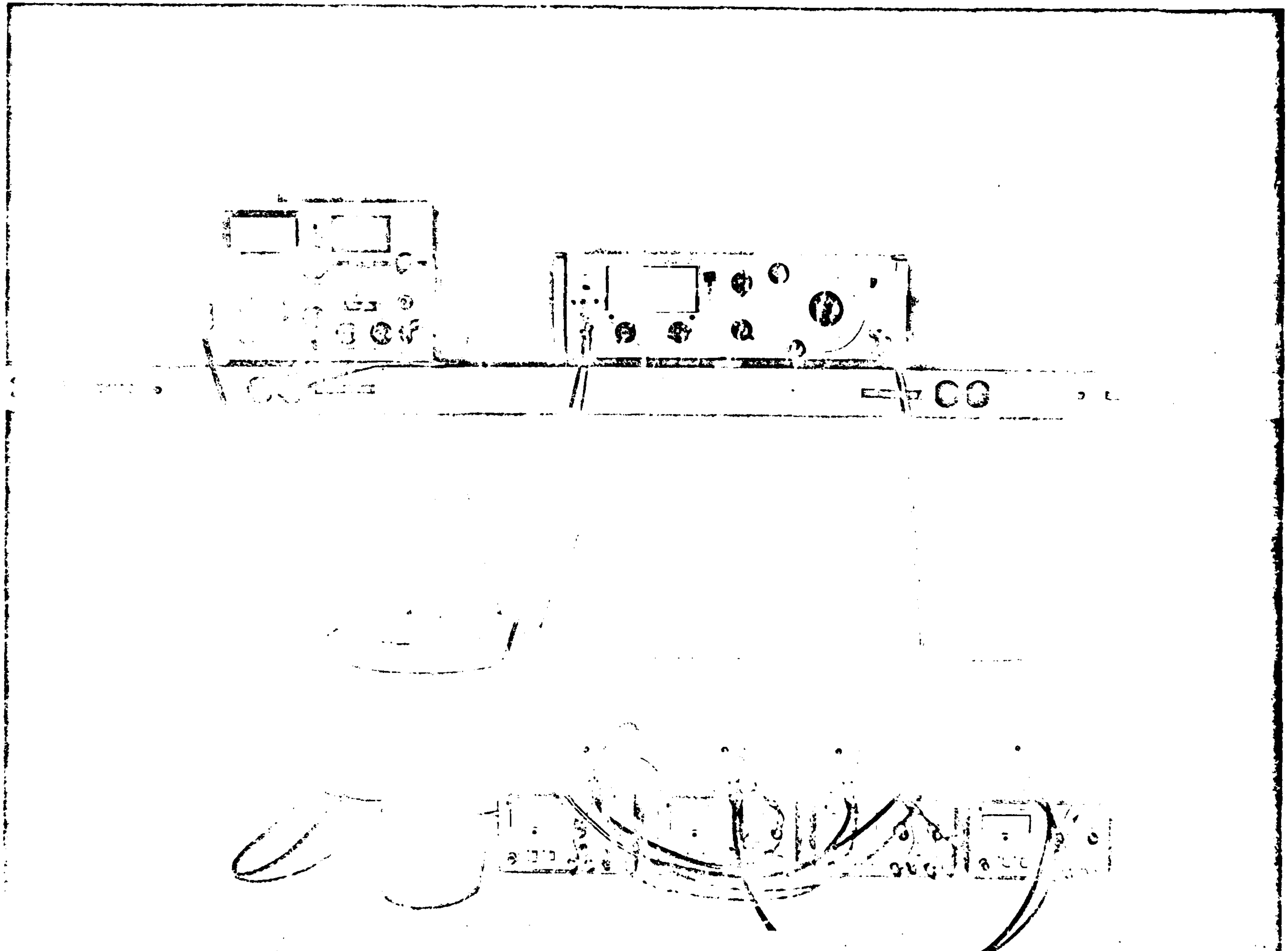

Figure 5. 12.6 MB/S Fiber Optic Data Link Test Set-Up

(b) Coaxial Cable System. ICN levels are shown in table XIX for 10 and 100 meters of coaxial (metallic) cable linking the system components.

TABLE XIX. IDLE CHANNEL NOISE OF 12.6 Mbs METALLIC CABLE SYSTEM

Channel Tested (No.)	Idle Channel Noise (dBrnc)			
	TSEC/CY-104 Looped Back	10-meter Coax Cable	TSEC/CY-104 Looped Back	100-meter Coax Cable
3	22	22	22	22
7	17	19	17	19
10	23	23	24	24
15	24	24	24	24
19	24	24	24	24
22	18	18	18	18

(2) Crosstalk. Baseline ICN and crosstalk levels are shown in tables XX and XXI for 10 and 100 meter lengths of Manufacturer C fiber optic cable and coaxial cable.

TABLE XX. CROSSTALK MEASUREMENT, 12.6 Mbs DATA LINK
(-16 dBm TONE INSERTED ON CHANNEL 2)

Channel Measured (No.)	Fiber Optic System				Metallic Cable System			
	10-meter		100-meter		10-meter		100-meter	
	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)
1	22	23	22	22	22	23	22	22
3	22	22	22	22	22	23	21	22
14	23	23	23	23	23	23	23	24
18	24	24	24	24	24	24	24	24

TABLE XXI. CROSSTALK MEASUREMENT, 12.6 Mbs DATA LINK
(-16 dBm TONE INSERTED ON CHANNEL 23)

Channel Measured (No.)	Fiber Optic System				Metallic Cable System			
	10-meter		100-meter		10-meter		100-meter	
	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)
7	21	21	21	21	21	21	20	20
11	21	21	21	21	21	21	21	21
22	20	20	20	20	20	21	20	20
24	17	17	17	17	17	17	18	18

(3) Distortion. Baseline distortion through the HY-12A and total distortion with 10 and 100 meters of fiber optic or coaxial cable in the system are shown in table XXII.

TABLE XXII. DISTORTION MEASUREMENT (12.6 Mbs ANALOG LINK)

Channel (No.)	Frequency (Hz)	Distortion (%)				
		HY-12A	Fiber Optic System		Metallic Cable System	
			10 meters	100 meters	10 meters	100 meters
2	1000	1.95	1.95	1.95	1.95	1.95
	2000	1.90	1.90	1.90	1.90	1.90
	3000	2.70	2.70	2.70	2.70	2.70
23	1000	2.00	2.00	2.00	2.00	2.00
	2000	2.00	2.00	2.00	2.00	2.00
	3000	2.90	2.90	2.90	2.90	2.90

(4) Bit Error Rate. Results for the Manufacturer C fiber optic system and the coaxial cable system were identical to those shown in paragraph 6b(4) of this report.

(5) Frequency Response

(a) The frequency response of the Manufacturer C fiber optic system, using T-603 modem SN 884 and T-608 modem SN 887, is shown in table XXIII and figure 3. The absolute output level at 1 MHz was 2.9 dBm.

(b) The frequency response of the Manufacturer C fiber optic system, using T-603 modem SN 881 and T-608 modem SN 888, is shown in table XXIV and figure 4. The absolute output level at 1 MHz was 2.9 dBm.

TABLE XXIII. FREQUENCY RESPONSE OF MANUFACTURER C 12.6 Mbs DATA FIBER OPTIC SYSTEM USING T-603 MODEM SN 884 AND T-608 MODEM SN 887

FREQ (kHz)	GAIN (dB)	FREQ (MHz)	GAIN (dB)
1	2.9	1	2.9
2	2.9	2	2.9
3	2.9	3	2.9
4	2.9	4	2.8
5	2.9	5	2.8
6	2.9	6	2.8
7	2.9	7	2.9
8	2.9	8	2.9
9	2.9	9	2.9
10	2.9	10	2.9
20	2.9	20	2.5
30	2.9	30	1.0
40	2.9	40	-1.1
50	2.9	50	-4.1
60	2.9	60	-6.7
70	2.9	70	-9.0
80	2.9	80	-14.1
90	2.9	90	-23.7
100	2.9		

TABLE XXIV. FREQUENCY RESPONSE OF MANUFACTURER C 12.6 Mbs DATA FIBER OPTIC SYSTEM USING T-603 MODEM SN 881 AND T-608 MODEM SN 888

FREQ (kHz)	GAIN (dB)	FREQ (MHz)	GAIN (dB)
1	2.8	1	2.9
2	2.9	2	2.8
3	2.9	3	2.7
4	2.9	4	2.6
5	2.9	5	2.6
6	2.9	6	2.6
7	2.9	7	2.6
8	2.9	8	2.6
9	2.9	9	2.6
10	2.9	10	2.6
20	2.9	20	2.7
30	2.9	30	1.7
40	2.9	40	-0.8
50	2.9	50	-3.7
60	2.9	60	-7.0
70	2.9	70	-11.7
80	2.9	80	-20.5
90	2.9	90	-29.1
100	2.9		

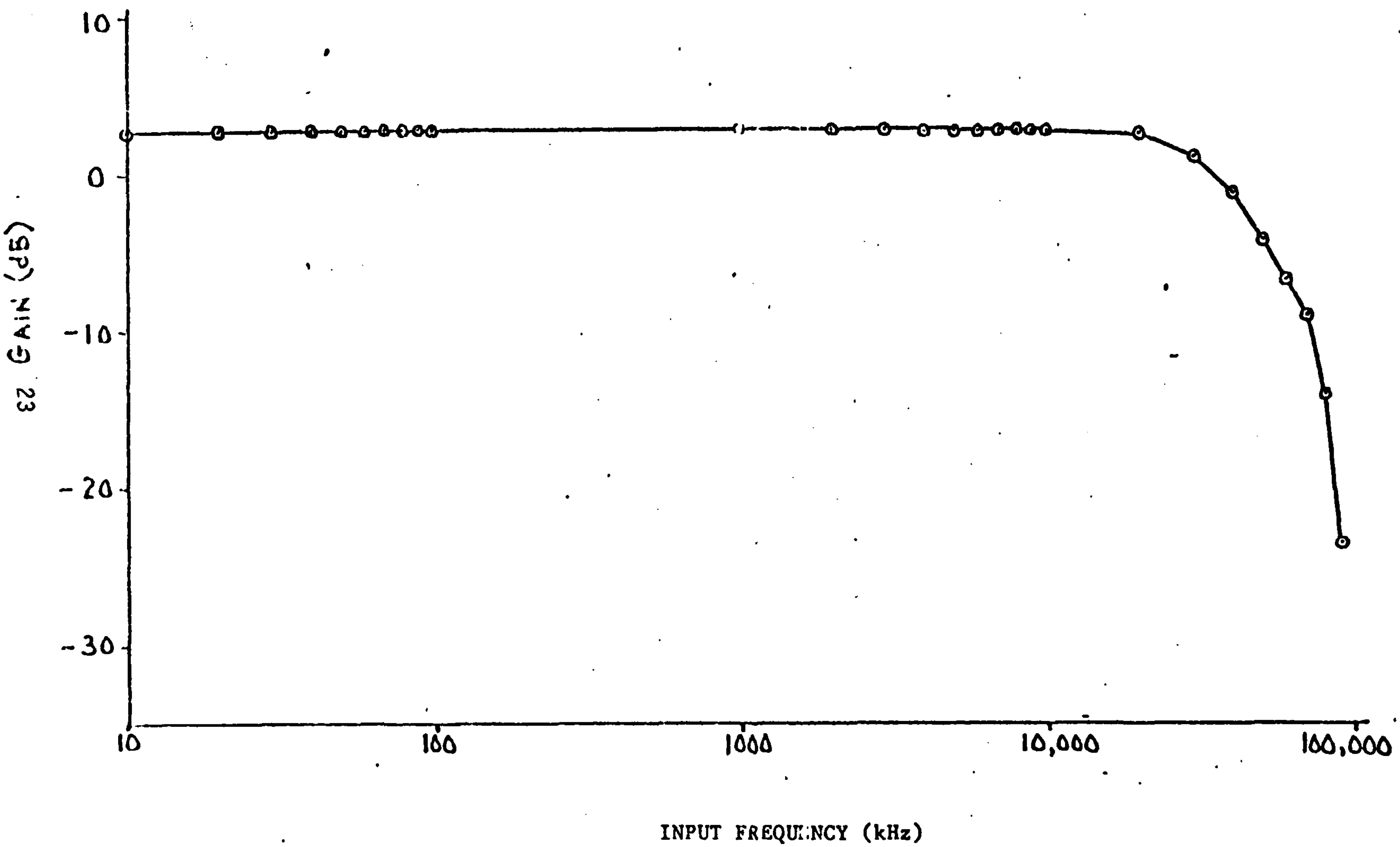

Figure 6 · Frequency response of Manufacturer C 12.6 Mbs data fiber optic system using T-603 modem SN 384 and T-608 modem SN 887.

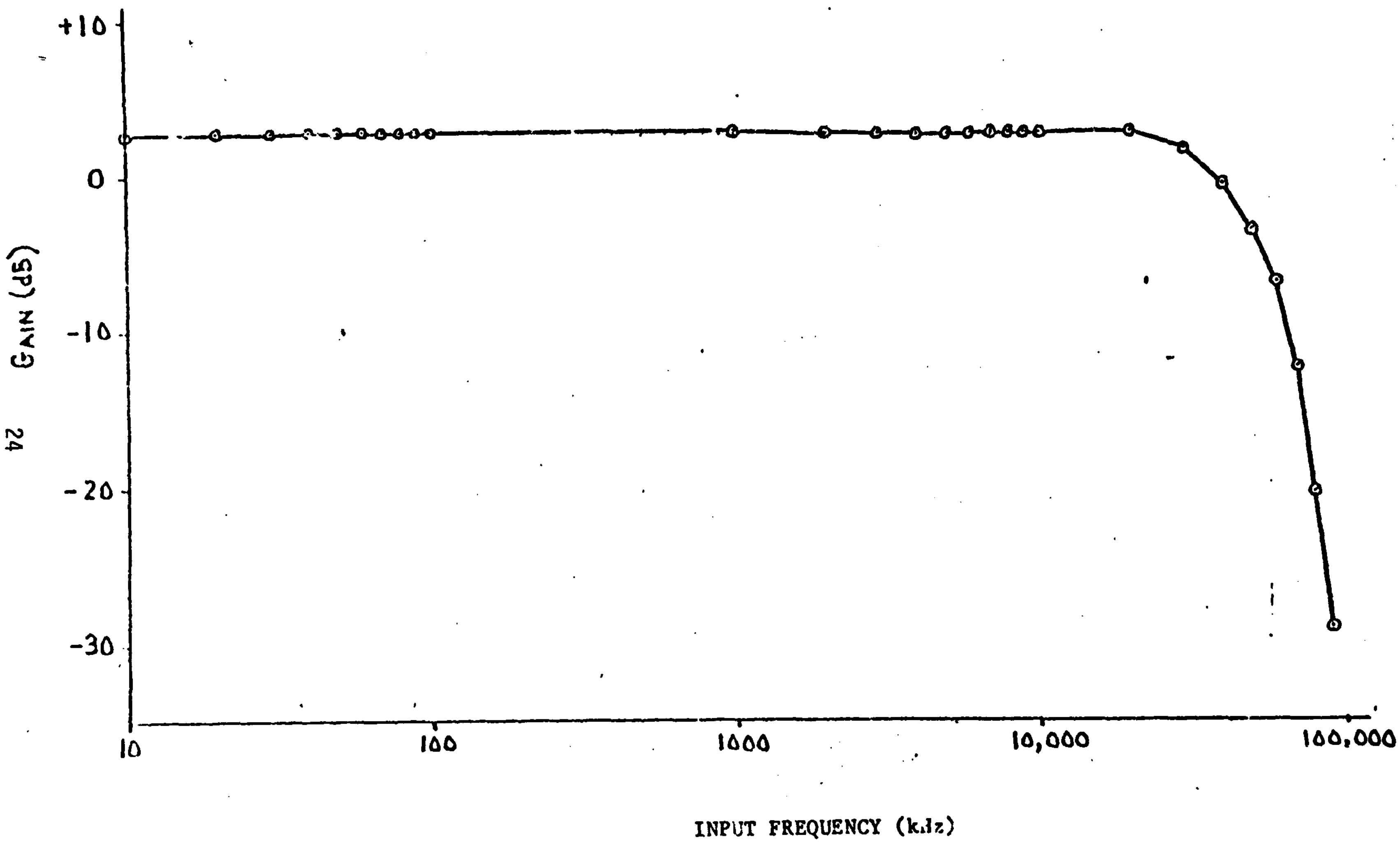

Figure 7 Frequency response of Manufacturer C 12.6 Mbs data fiber optic system using T-603 modem SN 881 and T-608 modem SN 888.

(6) Connect/Disconnect. Results are shown in table XXV for ICN reading that were made following every 10 connects/disconnects for both the Manufacturer C fiber optic cable and the equivalent coaxial cable.

TABLE XXV. CONNECT/DISCONNECT TEST (12.6 Mbs DATA)
(ICN IN dBrnc OF CHANNEL 2)

Number of Connects/Disconnects	Idle Channel Noise (dBrnc)	
	Fiber Optic	Metallic
0	23	23
10	23	23
20	23	23
30	23	23
40	23	23
50	23	23
60	23	23
70	23	23
80	23	23
90	23	23
100	23	23

(7) Cyclic Flexing

(a) Results for the Manufacturer C fiber optic cable are shown in table XXVI. See paragraph 6b(6)(b).

TABLE XXVI. CYCLIC FLEX TEST (12.6 Mbs) FOR MANUFACTURER C FIBER OPTIC CABLE

Number of Cycles	Optical Power (uW)	Number of Cycles	Optical Power (uW)
0	10	600	10
100	10	700	10
200	10	800	10
300	10	900	10
400	10	1000	10
500	10		

(b) Results for the coaxial cable are shown in table XXVII.

TABLE XXVII. CYCLIC FLEX TEST FOR COAXIAL CABLE

Number of Flex Cycles	Voltage Measured (volts peak-to-peak)
0	1
10	1
20	1
30	1
40	1
50	1
60	1
70	1
80	1
90	1
100	1

RESULTS

a. 4-kHz Voice Link

(1) Idle Channel Noise. ICN levels measured on the Manufacturer A fiber optic link ranged from 24 to 28 dBrnc. They were at least 29 dB greater than those measured on any pair of the 26 pair cable.

(2) Crosstalk. On the Manufacturer A fiber optic link, crosstalk added from 1 to 5 dB noise to the baseline ICN level. No measurable change in the baseline level of the ICN of the 26 pair cable was observed; however, changes may have occurred that were less than the sensitivity of the test instrumentation.

(3) Distortion. The Manufacturer A fiber optic link added from 0.65 to 1.17 percent distortion to the input signal. No more than 0.002 percent distortion was added by the 26 pair cable. For both links, the percentage of distortion added was generally insensitive to changes in input frequency.

(4) Frequency Response

(a) Response curves were fairly linear and negatively sloped over the frequency range 1 to 4 kHz; more erratic behavior was typically observed in the frequency range 200 to 900 Hz.

(b) The slope of the response curve varied significantly between channel 9 and channel 11. As measured from the 1 kHz point, a 3-dB drop in gain occurred at approximately 3 kHz on channel 9 and 4 kHz on channell 11; thus, channel 9 exhibited a "usable" frequency bandwidth for channel 11.

(c) As previously noted, the optic cable did not seat well on the modem connectors; movement of the cable was capable of changing output by up to 6 dB. This equipment flaw is considered responsible for the noticeable variation in the absolute magnitudes of the gain shown in the frequency response curves.

(5) The condition/quality of the Manufacturer A fiber optic link was clearly not up to par for a valid comparison with a 26 pair cable link as evidenced by the following observations:

(a) Only channels 9 through 12 could be tested due to modem malfunction.

(b) The fiber optic cable did not seat well on the modem connectors.

(c) Performance characteristics were unexpectedly poor.

(d) The modems were developmental items built by Manufacturer A for CORADCOM. Apparently, they did not incorporate the refinements that one would expect in a production model.

b. 1.544 Mbs Data Link

(1) Idle Channel Noise. The ICN readings were similar for 10 or 100 meter lengths of cable for both the Manufacturer B fiber optic link and the coaxial (metallic) cable link. Each link typically added no more than 2 dB of noise to the baseline ICN of the looped back TSEC/CY-104.

(2) Crosstalk. Crosstalk induced additions to baseline ICN levels were similar for both 10 or 100 meter lengths of cable for both the Manufacturer B fiber optic link and the coaxial cable link. For each link, crosstalk effects typically added less than 1 dB of noise to the baseline ICN.

(3) Distortion. When compared to the distortion induced by the HY-12A, neither 10 or 100 meter lengths of cable for the Manufacturer B fiber optic link or the metallic, coaxial cable link produced measurable distortion.

(4) Bit Error Rate. The point estimate of the BER for a T-1 bit rate input into the fiber optic system with 10 or 100 meters of cable or into the 10 meter, coaxial cable link is less than or equal to 2.2×10^{-9} errors/bit. When 100 meters of coaxial cable were used, the BER was significantly increased to about 6×10^{-6} errors/bit.

(5) Connect/Disconnect. Neither the Manufacturer B fiber optic link nor the coaxial cable link experienced any change in ICN level following 100 cycles of cable connecting and disconnecting.

(6) Cyclic Flexing. Optic power output dropped significantly following 2000 cyclic flexes of the fiber optic cable. The optical power output loss was about 2 microwatts (roughly 17 percent).

(7) Installation/Recovery Time

(a) Installation/recovery times for 10 meters of fiber optic cable and modems were, in general, slightly greater than those recorded for 10 meters of coaxial cable. Times were significantly greater for 100 meters of fiber optic cable and modems as compared to 100 meters of coaxial cable, especially when these tasks were performed by only one soldier.

(b) This observed time discrepancy is attributed to the following causes:

1 During installation (recovery), six connections (disconnections) were required to install (recover) the fiber optic cable and modems as compared to only two connections (disconnections) for the coaxial cable link.

2 The fiber optic modems had to be turned on (off).

3 The fiber optic cable was felt to be more unruly and, thus, harder to roll (unroll) and handle.

4 The test personnel were less experienced with fiber optic links than metallic cable links.

(c) More precise studies could have been conducted by a human factors engineer. However, USACEEIA personnel did not believe that such work would be cost-effective at this point in the project (see ref 1c, para 2i).

c. 12.6 Mbs Data Link

(1) Idle Channel Noise. The ICN readings were similar for 10 or 100 meters of cable for both the Manufacturer C optic link and the coaxial cable link. No more than 2 dB of ICN was added to baseline (looped back TSEC/CY-104) readings by either link.

(2) Crosstalk. No crosstalk induced additions to baseline ICN levels were noted for either 10 or 100 meters of Manufacturer C fiber optic cable. For the 10 and 100 meter lengths of coaxial cable, crosstalk effects typically added less than 1 dB of noise to the baseline ICN.

(3) Distortion. When compared to the distortion caused by the HY-12A, neither 10 or 100 meter lengths of cable for the Manufacturer C optic link or the coaxial link produced measurable distortion.

(4) Bit Error Rate. The point estimte of the BER for a T-1 bit rate input into the fiber optic system with 10 or 100 meters of Manufacturer C cable or into the 10 meter, coaxial cable link is less than or equal to 2.2×10^{-9} errors/bit. When 100 meters of coaxial cable were used, the BER was significantly increased to about 6×10^{-6} errors/bit.

(5) Frequency Response. The Manufacturer C fiber optic link demonstrated a virtually flat frequency response from 1 kHz to 1 MHz. The link displayed a usable frequency bandwidth of more than 30 MHz. This link, which was designed for 20 MHz analog use, incorporated an automatic gain control (AGC) in the modems; this feature was primarily responsible for the excellent frequency response characteristics of this link.

(6) Connect/Disconnect. Neither the Manufacturer C optic link nor the coaxial cable link experienced any measurable change in ICN level following 100 cycles of cable connecting and disconnecting.

(7) Cyclic Flexing. No measurable change in the optic power output of the Manufacturer C optic cable or the output of the coaxial cable was observed following 2000 flexes of the fiber optic cable and 100 flexes of the coaxial cable.

7. ANALYSIS

a. 4-kHz Voice Link

(1) The Manufacturer A fiber optic link displayed more idle channel noise, crosstalk, and distortion than the 26 pair metallic cable link. In addition, the frequency response of the fiber optic link indicated that the "usable" channel bandwidth was less than 3.2 kHz, which is an approximate standard for commercial voice telephone applications. The significance of these problems would depend on the system in which the fiber optic link was used.

(2) The poorer performance of the Manufacturer A fiber optic link can be attributed to several factors:

(a) The fiber optic link included two active electronic devices (the modems) whereas the 26 pair cable link was completely passive. Performance degradation is most likely the product of the fiber optic modems and not the fiber optic cable.

(b) As previously noted, the fiber optic modems were developmental models and in poor condition.

(3) Consequently, this test does not present a fair comparison between fiber optic links at voice frequency and the corresponding 26 pair cable link. A more valid comparison could be made if production models of fiber optic modems in a good state-of-repair were available for testing.

b. 1.544 Mbs Link

(1) Measured ICN, crosstalk effects, and signal distortion were nearly identical for the Manufacturer B fiber optic link and the coaxial cable link. BER was significantly lower for the fiber optic link with 100 meters of cable than for the same length of coaxial cable (at a T-1 data input rate).

(2) Although 100 cycles of connecting and disconnecting the Manufacturer B fiber optic cable and the coaxial cable had no effect on ICN readings, 2000 cyclic flexes of the fiber optic cable caused a significant loss in optical power output (more than 10 percent) in the fiber optic cable. Thus, the Manufacturer B fiber optic cable would experience a gradual deterioration in performance if subjected to repeated flexing in its intended field environment.

(3) In spite of the lighter weight of the fiber optic cable, installation and recovery times were longer for the Manufacturer B fiber optic link than the coaxial link due to the presence of the fiber optic modems, which required three times as many cable connections and disconnections. Time differences were most pronounced for one-man installation or recovery using 100 meters of cable.

(4) Thus, the Manufacturer B fiber optic link demonstrated similar or improved electrical performance to the coaxial cable link, but required more time to install or recover and experienced gradual deterioration of output power caused by repeated cyclic flexes of the cable.

c. 12.6 Mbs Data Link

(1) The Manufacturer C fiber optic link's electrical performance was essentially the same (or better for BER) as that of the coaxial cable link. Repeated cyclic flexing and connecting/disconnecting of the cable caused no measurable change in the performance of the fiber optic link. However, as previously mentioned, installation/recovery times would most likely be longer for the fiber optic link than the coaxial cable link.

(2) The Manufacturer C fiber optic link used state-of-the art components that are being used in commercial applications. Therefore, this comparison with the coaxial cable link is considered to be a valid one.

d. When used in zero length intrastation applications, the better electrical performance of fiber optic cable in comparison to the equivalent metallic cable appears to compensate for the degradation in electrical performance caused by the presence of the modems required in the fiber optic link. The lighter weight of the fiber optic cable does not compensate for the additional connections/disconnections required in the fiber optic links tested when installation/recovery time is considered.

8. CONCLUSIONS

a. 4 kHz Analog

The 4kHz fiber optic analog link was poorer in all catagories of tests than the 26 pair cable. This was due to the fact that the manufacturer A fiber optic link was neither in the state-of-repair nor of adequate quality of construction to permit a valid comparison with the equivalent 26 pair metallic cable link used in a 4 kHz voice, zero length intrastation application. Further, Manufacturer A fiber optic link was not an off-the-shelf modem, but was the result of an exploratory development contract.

b. 1.544 Mb/s Link

(1) The degradation of power output with 200 cyclic flexes of the fiber optic cable (greater than 10%) is considered to be trivial considering the gain margin available at 100 M. In addition, 2000 flexes is considered to be far more than would be encountered in a normal equipment lifetime. Therefore, the fiber optic cable is considered to be more than rugged enough for intrastation interconnection application.

(2) The increase installation and recovery times for the fiber optic cable was due to the use of BAMI/TTL units to interface the fiber optic modems with the TSEC CY-104 1.544 Mb/s multiplexer. This ad hoc interface was required since the CY-104 Digital bit stream input/output was not designed for

a fiber optic interface. This added interface device would not be required in a properly engineered fiber optic transmission system.

(3) The increased bit error rate for the coax cable at the 100 meter distance was due to operating the equipment beyond its design limit (150'). This does, however, underline the increased flexibility of equipment layout possible with fiber optic cable which had no errors at the 100 meter distance.

(4) If fiber optics is to be used for this link, the present coax cable driver electronics (bi-polar) would be replaced by the optical cable driver electronics (LED transmitter and PIN photodiode detector). The number of interconnects would then be the same as for coax cable: one data cable and one timing cable.

c. 12.6 Mb/s

(1) There was no degradation in idle channel noise, distortion, crosstalk, or bit error rate when fiber optics was used to replace coax cable at the 12.6 Mb/s rate. This result was in spite of the fact that no commercial digital fiber optic modem could be found which would take a 12.6 Mb/s bi-polar signal as an input. The plus and minus one volt signal was treated as an analog signal and was passed with little distortion over a 20 MHz analog fiber optic link.

d. General Conclusions

(1) The technical feasibility of using commercial fiber optic data links with standard strategic communications transmission multiplex equipment in an intrastation application environment was demonstrated.

(2) Fiber optic links greatly increase the flexibility of equipment layout since the cable is non-conductive electric and neither radiates nor picks up electromagnetic radiation.

(3) Most available commercial fiber optic modems will probably not meet TEMPEST requirements.

(4) The commercial fiber optic systems available at the time selection of candidate items for evaluation was made, were not designed to interface optimally with the DCS multiplexers then in use, i.e., TSEC CY-104, AN/FCC-97.

(5) Commercial cable fiber optic systems are rugged and handle easily enough for intrastation applications in the DCS and other fixed plant environments.

(6) Attention must be given to design and handling of fiber optic connectors in fiber optic interconnects to prevent losses due to misalignment or improper seating of connectors.

9. RECOMMENDATIONS

a. PCM multiplexers, channel banks, digital radios, and digital data processing equipment should contain integral fiber optic transmitters and receivers with optical ports (connectors) for fiber optic interconnectivity.

b. A family of fiber optic transmitters and receivers should be developed for inplementation as integral parts or appliques to DCS data transmission equipment. Due to the large number of small commercially available fiber optic modems, the development required may be minimal, resulting in more of a repackaging effort than a development.

c. It is not considered cost effective to use fiber optics for voice frequency channels (space multiplexing), due to the cost of fiber optic transmitters and receivers. Application of Fiber Optics to digital transmission/multiplexing is recommended with a minimum rate of at least the T-1 rate (1.544 Mb/s) as a cost effective consideration.

APPENDIX A

INITIAL TESTING

AND

TEST RESULTS

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1. 4 KHZ VOICE LINK

1.1 IDLE CHANNEL NOISE (ICN)

A. Equipment Used.

1. Fiber Optic System.

a. 4-kHz fiber optic modems (2 ea).

b. 300 meters fiber optic cable.

c. J-1077 A/V junction box (2 ea).

d. Transmission impairment measuring set (HP 4940 AV, SN 01A00688).

2. Metallic Cable System.

a. 26 pair cable (250 ft).

b. J-1077 A/V junction box (2 ea).

c. Transmission impairment measuring set (HP 4940A, SN 01A00688).

B. Procedure.

1. Fiber Optic System.

a. Test set up using figure 1.

b. HP-4940A TIMS was set up in the following manner. Switches were set for message circuit noise, noise filter selection to C-message weighting and circuit impedance of 600 ohms. The distant end of the channel was terminated at 600 ohms.

2. Metallic Cable System -- Same procedure as B.1 above except using figure 2.

C. Test Data.

TABLE I. IDLE CHANNEL NOISE OF 4-KHZ FIBER OPTIC SYSTEM

Channel No.	Idle Channel Noise (dBrnc)
9	24
10	28
11	25
12	24

Note: Channels 9-12 on fiber optic modem were the only channels that were operational.

Idle channel noise for metallic cable system was lower than HP-4940A measurement capabilities. HP-4940A measurement range is 20 to 90 dBrnc.

1.2 CROSSTALK

A. Equipment Used.

1. Fiber Optic System.

a. 4-kHz fiber optic modems (2 ea).

b. 300 meters fiber optic cable.

c. J-1077 A/V junction box (2 ea).

d. Test oscillator (HP 204C, SN 808-01789).

e. Transmission impairment measuring set (HP-4940A, TIMS, SN 01A00688).

2. Metallic Cable System.

a. 26 pair cable (250 ft).

b. J-1077 A/V junction box (2 ea).

c. Test oscillator (HP-204C, SN 808-01789).

d. Transmission impairment measuring set (HP-4940A, TIMS, SN 01A00688).

B. Procedure.

1. Fiber Optic System.

a. Test set up using figure 3.

b. HP-2046 test oscillator was set at 1000 Hz at -10 dBm and connected to transmit end of J-1077 A/V junction box. HP-4940A TIMS was set up in the following manner. Switches were set for message circuit noise, noise filter selection to C-message weighting and circuit impedance of 600 ohms. The TIMS was connected to receive end of adjacent channel to be tested.

2. Metallic Cable System -- Same procedure as B.1 above except using figure 4.

C. Test Data.

TABLE II. CROSSTALK OF 4-KHZ FIBER OPTIC SYSTEM

Channel Tested (No.)	Idle Channel Noise of Channel Tested (dBrnc)	Crosstalk Measurement (dBrnc)			
		1000 Hz -10 dBm Tone on Channel 9	1000 Hz -10 dBm Tone on Channel 10	1000 Hz -10 dBm Tone on Channel 11	1000 Hz -10 dBm Tone on Channel 12
9	24	--	29	27	26
10	28	29	--	29	29
11	25	26	27	--	30
12	24	27	25	26	--

1.3 DISTORTION

A. Equipment Used.

1. Fiber Optic System.

a. 4-kHz fiber optic modem (2 ea).

b. [illegible]00 meters fiber optic cable

c. J-1077 A/V junction box (2 ea).

d. Test oscillator (HP-204C, SN 808-01789).

e. Distortion analyzer (HP-334A, SN 1140A07152).

f. Frequency selective voltmeter (Rycom 6010, SN 122).

g. Balanced to unbalanced circuit transformer.

2. Metallic Cable System.

a. 26 pair cable (250 ft).

b. J-1077 A/V junction box (2 ea).

c. Test oscillator (HP-204C, SN 808-01789).

d. Distortion analyzer (HP-334A, SN 1140A07152).

e. Frequency selective voltmeter (Rycom 6010, SN 122).

f. Balanced to unbalanced circuit transformer.

B. Procedure.

1. Base line measurement.

a. Test set up using figure 5.

b. Test oscillator HP-204C was set at 1000 Hz at -10 dBm and connected to balanced side of transformer, and terminated at 600 ohms impedance. The distortion analyzer HP-334A was connected to the unbalanced side of the transformer and measurements taken. Procedure repeated for 2000 and 3000 Hz.

2. Fiber Optic System

a. Test set up using figure 6.

b. Test oscillator HP-204C was set at 1000 Hz at -10 dBm with the signal sent through the system, connected to the balanced side of transformer, and terminated at 600 ohms impedance. The frequency selection voltmeter Rycom 6010 was set to 600 ohms and also connected to the balanced side of the transformer. The distortion analyzer HP-334A was connected to the unbalanced side of the transformer. The frequency selective voltmeter was tuned to 1000 Hz and the power output of the test oscillator was adjusted until proper levels were read on the voltmeter. Distortion level readings were then taken. This procedure was then repeated for 2000 Hz and 3000 Hz.

3. Metallic cable system -- same procedure as B.2 above except using figure 7.

C. Data No Data

TABLE III. 4 KHZ VOICE DISTORTION

Frequency of -10 dBm Test Tone (Hz)	Baseline measurement	Distortion Levels (%) Fiber Optic System Chan 9	Chan 10	Chan 11	Chan 12	Metallic Cable System Chan 1	Chan 13	Chan 14	Chan 26
1000	0.072	1.2	0.7	1.25	1.95	0.072	0.072	0.072	0.072
2000	0.046	1.0	0.7	1.15	1.85	0.048	0.048	0.048	0.048
3000	0.038	0.95	0.8	1.2	1.75	0.040	0.040	0.040	0.040

2. 1.544 MBS DATA LINK

2.1 IDLE CHANNEL NOISE

A. Equipment Used.

1. Fiber Optic System.

a. 1.544 Mbs data fiber optic modems (4 ea).

b. Fiber optic cable (10- and 100-meter lengths).

c. BAMI/TTL interface converter (2 ea, SN 002604 and 002605).

d. TSEC/CY-104 multiplexer (HY-12A, SN 139 and HN-74, SN 500).

e. AN/FCC-97 multiplexer (SN 01J0033).

f. Transmission impairment measurement set (HP-4940A TIMS, SN 01A00688).

2. Metallic Cable System.

a. Coax cable RG-59 (10- and 100-meter lengths).

b. TSEC/CY-104 multiplexer (HY-12A, SN 139 and HN-74, SN 500).

c. AN/FCC-97 multiplexer (SN 01J0033).

d. Transmission impairment measuring set (HP-4940A TIMS, SN 01A00688).

B. Procedure.

1. TSEC/CY-104 Loop Back (NRZ Loop J107 to J108).

a. Test set up using figure 8.

b. HP-4940A TIMS was set up in the following manner. Switches were set for message circuit noise, noise filter selection to C-message weighting, and circuit impedance of 600 ohms. The transmit channel of the TSEC/CY-104 was terminated at 600 ohms. The noise level was checked at the front receiver patch on the 7120-05 channel unit card of the TSEC/CY-104.

2. Fiber Optic System -- Same procedure as in B.1 above except using figure 9.

3. Metallic Cable System -- Same proceudres as in B.1 above except using figure 10.

C. Test Data.

TABLE IV. IDLE CHANNEL NOISE OF 1.544 MBS FIBER OPTIC SYSTEM

Channel Tested (No.)	Idle Channel Noise (dBrnc)			
	TSEC/CY-104 Looped Back	10-meter Fiber Optic Cable	TSEC/CY-104 Looped Back	100-meter Fiber Optic Cable
3	22	22	22	22
7	18	20	18	20
10	24	24	24	24
15	23	24	23	24
19	24	24	24	24
22	18	18	18	18

TABLE V. IDLE CHANNEL NOISE OF 1.544 MBS METALLIC CABLE SYSTEM

Channel Tested (No.)	Idle Channel Noise (dBrnc)			
	TSEC/CY-104 Looped Back	10-meter Coax Cable	TSEC/CY-104 Looped Back	100-meter Coax Cable
3	22	24	22	22
7	18	22	18	20
10	23	23	24	24
15	22	24	22	24
19	24	24	24	24
22	18	20	18	18

2.2 CROSSTALK

A. Equipment Used.

1. Fiber Optic System.

a. Fiber optic modems (4 ea).

b. Fiber optic cable (10- and 100-meter lengths).

c. BAMI/TTL interface converter (2 ea, SN 002604 and 002605).

d. TSEC/CY-104 multiplexer (HY-12A, SN 139 and HN-74, SN 500).

e. AN/FCC-97 multiplexer (SN 01J0033).

f. Transmission impairment measurement set (HP-4940A TIMS, SN 01A00688).

g. Test oscillator (HP-204C, SN 808-01789).

2. Metallic Cable System.

a. Coax cable RG-59 (10- and 100-meter lengths).

b. TSEC/CY-104 multiplexer (HY-12A, SN 139 and HN-74, SN 500).

c. AN/FCC-97 multiplexer (SN 01J0033).

d. Transmission impairment measuring set (HP-4940A TIMS, SN 01A00688).

e. Test oscillator (HP-204C, SN 808-01789).

B. Procedure.

1. Fiber Optic System.

a. Test set up using figure 11.

b. HP 204C test oscillator was set at 1000 Hz and a -16 dBm tone was inserted into the transmit patch on the 7120-05 channel unit card of the TSEC/CY-104. The receive patch of the disturbing channel was terminated at 600 ohms. The HP-4940A TIMS was set up in the following manner. Switches were set for message circuit noise, noise filter selection to C-message weighting, and circuit impedance of 600 ohms. The TIMS was then connected to the receive patch of the 7120-05 channel unit card of the disturbed channel. The transmit patch of the 7120-05 channel unit card was terminated at 600 ohms. The tone was inserted on channels 2 and 23, and the physically and electrically adjacent channels to both were tested.

2. Metallic Cable System -- Same procedure as in B.1 above except using figure 12.

C. Test Data.

TABLE VI. CROSSTALK MEASUREMENT, 1.544 MBS DATA LINK
(-16 DBM TONE INSERTED ON CHANNEL 2)

Channel Measured (No.)	Fiber Optic System 10-meter ICN (dBrnc)	Fiber Optic System 10-meter Crosstalk (dBrnc)	Fiber Optic System 100-meter ICN (dBrnc)	Fiber Optic System 100-meter Crosstalk (dBrnc)	Metallic Cable System 10-meter ICN (dBrnc)	Metallic Cable System 10-meter Crosstalk (dBrnc)	Metallic Cable System 100-meter ICN (dBrnc)	Metallic Cable System 100-meter Crosstalk (dBrnc)
1	24	24	24	24	24	25	24	24
3	23	24	23	23	23	24	23	23
14	23	24	23	23	23	24	23	24
18	25	25	24	24	25	25	24	24

TABLE VII. CROSSTALK MEASUREMENT, 1.544 MBS DATA LINK
(-16 DBM TONE INSERTED ON CHANNEL 23)

Channel Measured (No.)	Fiber Optic System 10-meter ICN (dBrnc)	Fiber Optic System 10-meter Crosstalk (dBrnc)	Fiber Optic System 100-meter ICN (dBrnc)	Fiber Optic System 100-meter Crosstalk (dBrnc)	Metallic Cable System 10-meter ICN (dBrnc)	Metallic Cable System 10-meter Crosstalk (dBrnc)	Metallic Cable System 100-meter ICN (dBrnc)	Metallic Cable System 100-meter Crosstalk (dBrnc)
7	22	22	22	22	21	21	21	21
11	18	18	18	19	20	20	21	22
22	19	19	20	20	19	19	21	21
24	17	17	17	17	17	17	20	20

2.3 DISTORTION

A. Equipment Used.

1. Fiber Optic System.

a. Fiber optic modems (4 ea).

b. Fiber optic cables (10- and 100-meter lengths).

c. BAMI/TTL interface converter (2 ea, SN 002604 and 002605).

d. TSEC/CY-104 multiplexer (HY-12A, SN 139 and HN-74, SN 500).

e. AN/FCC-97 multiplexer (SN 01J0033).

f. Balanced to unbalanced circuit transformer.

g. Test oscillator (HP-204C, SN 808-01789).

h. Frequency selective voltmeter (Rycom 6010, SN 122).

i. Distortion analyzer (HP-334A, SN 1140A07152).

2. Metallic Cable System.

a. Coax cable RG-59 (10- and 100-meter lengths).

b. TSEC/CY-104 multiplexer (HY-12A, SN 139 and HN-74, SN 500).

c. AN/FCC-97 multiplexer (SN 01J0033).

d. Balanced to unbalanced circuit transformer.

e. Test oscillator (HP-204C, SN 808-01789).

f. Frequency selective voltmeter (Rycom 6010, SN 122).

i. Distortion analyzer (HP-334A, SN 1140A07152).

B. Procedure.

1. Baseline Measurement.

a. Test set up using figure 5.

b. Test oscillator HP-204C was set at 1000 Hz and -16 dBm, connected to the balanced side of the transformer and was terminated at 600 ohms impedance. The distortion analyzer HP-334A was connected to the unbalanced side of the transformer and measurements taken. The procedure was then repeated for 2000 Hz and 3000 Hz. Coax cable length between transformer and distortion analyzer was then varied, using 1-, 10-, and 100-meter lengths.

2. Distortion Measurement of HY-12A.

a. Test set up using figure 13.

b. The test oscillator HP-204C was set at 1000 Hz and inserted a -16 dBm tone into the transmit patch on the 7120-05 channel unit card of the HY-12A. The receive patch on the 7120-05 channel unit card was then connected to the balanced side of the transformer and terminated at 600 ohms. The frequency selective voltmeter Rycom 6010, set at 600 ohms bridging, was also connected to the balanced side of the transformer. The distortion analyzer HP-334A was connected to the unbalanced side of the transformer. The frequency selective voltmeter was tuned to 1000 Hz and output of the test oscillator adjusted until proper signal levels were observed. Distortion measurements were then taken. This procedure was repeated for 2000 Hz and 3000 Hz. Both channels 2 and 23 were measured.

3. Fiber Optic System -- Same procedure as B.2 above except using figure 15.

C. Test Data.

TABLE VIII. DISTORTION MEASUREMENT BASELINE READINGS

Test Tone Frequency (Hz)	Distortion (%) 1 meter	10 meters	100 meters
1000	0.072	0.072	0.072
2000	0.044	0.050	0.052
3000	0.038	0.045	0.046

TABLE IX. DISTORTION MEASUREMENT (1.544 MBS DATA LINK)

Channel (No.)	Frequency (Hz)	Distortion (%) HY-12A	Fiber Optic System 10 meters	Fiber Optic System 100 meters	Metallic Cable System 10 meters	Metallic Cable System 100 meters
2	1000	1.95	1.95	1.95	1.95	1.95
	2000	1.90	1.90	1.90	1.90	2.00
	3000	2.70	2.70	2.70	2.70	2.70
23	1000	2.00	2.00	2.00	2.00	2.00
	2000	2.00	2.00	2.00	2.00	2.00
	3000	2.90	3.00	2.90	2.90	2.90

2.4 BIT ERROR RATE

A. Equipment Used.

1. Condition diphase pattern (CDP) generator and error correlator (CORADCOM GFE).

2. Fiber optic cable (10- and 100-meter lengths).

3. Fiber optic modem.

B. Procedure.

1. Test set up using figure 16.

2. Output of CDP generator was connected to the data input terminal of the optical modem. The optical side of the modem was looped back and the data output of the optical modem was connected to the input terminal of the CDP generator and correlator. The CDP generator and correlator were operated at both 16 and 32 kbs.

C. Test Data.

TABLE X. BIT ERROR COUNT (1.544 MBS LINK) (16/32 KBS CDP TEST)

Input Data Rate (kbs)	Number of Hours Test Was Run	Number of Errors	
		10-meter	100-meter
16	100	0	0
32	50	0	0

2.5 CONNECT/DISCONNECT

A. Equipment Used.

1. Fiber Optic System.

a. Fiber optic modems (4 ea).

b. Fiber optic cable (10-meter length).

c. BAMI/TTL interface converter (2 ea, SN 002604 and 002605).

d. TSEC/CY-104 multiplexer (HY-12A, SN 139 and HN-74, SN 500).

e. AN/FCC-97 multiplexer (SN 01J0033).

f. Transmission impairment measurement set (HP-4940A TIMS, SN 01A00688).

g. Test oscillator (HP-204C, SN 808-01789).

2. Metallic Cable System.

a. Coax cable RG-59 (10-meter length).

b. TSEC/CY-104 multiplexer (HY-12A, SN 139 and HN-74, SN 500).

c. AN/FCC-97 multiplexer (SN 01J0033).

d. Transmission impairment measuring set (HP-4940A TIMS, SN 01A00688).

B. Procedure.

1. Fiber Optic System.

a. Test set up using figure 9.

b. The fiber optic cable between the two optical modems carrying data was disconnected and reconnected 100 times. Idle channel noise was measured every 10 times.

2. Metallic Cable System.

a. Test set up using figure 10.

b. The coax cable between the TSEC/CY-104 and the AN/FCC-97 was disconnected and reconnected 100 times. Idle channel noise was measured every 10 times.

C. Test Data.

TABLE XI. CONNECT/DISCONNECT TEST (ICN IN DBRNC OF CHANNEL 2)

Number of Connects/Disconnects	Idle Channel Noise (dBrnc) Fiber Optic	Metallic
0	23	23
10	23	23
20	23	23
30	23	23
40	23	23
50	23	23
60	23	23
70	23	23
80	23	23
90	23	23
100	23	23

2.6 CYCLIC FLEXING

A. Equipment Used on Fiber Optic System.

1. Optical modem.

2. Fiber optic cable (10-meter length).

3. Frequency synthesizer (SYNTEST S1-102, SN 10-2039).

4. Optical power meter (United Detector Technology, Mdl 40X, SN 46088).

B. Procedure.

1. Test set up using figure 17.

2. The frequency synthesizer was set at 1 MHz, 1-volt peak-to-peak square wave. The output was inserted into the optical modem. Optical power output was measured with the optical power meter. The cable was flexed over a mandrel 2.5 times the diameter of the cable. Power readings at the end of the cable were measured every 100 cycles.

C. Test Data.

TABLE XII. CYCLIC FLEX TEST

Number of Cycles	Optical Power (uW)	Number of Cycles	Optical Power (uW)	Number of Cycles	Optical Power (uW)	Number of Cycles	Optical Power (uW)
0	12	600	11	1100	11	1600	10
100	12	700	11	1200	11	1700	10
200	12	800	11	1300	11	1800	10
300	12	900	11	1400	11	1900	10
400	11	1000	11	1500	11	2000	10
500	11						

2.7 INSTALLATION/RECOVERY

A. Equipment Used.

1. Fiber Optic Systems.

a. Optical modems (4 ea).

b. Fiber optic cable (10- and 100-meter lengths).

c. BAMI/TTL interface converter (2 ea).

d. TSEC/CY-104.

e. AN/FCC-97.

2. Metallic Cable Systems.

a. Coax cable RG-59 (10- and 100-meter lengths).

b. TSEC/CY-104.

c. AN/FCC-97.

B. Procedure.

1. Fiber optic system set up using figure 18.

2. Metallic cable system set up using figure 19.

3. The times measured apply only to the time needed to unroll or roll the cable and connect or disconnect the interface equipment. The TSEC/CY-104 and AN/FCC-97 were previously installed.

C. Test Data.

TABLE XIII. INSTALLATION TIME

Trial Number	Installation Time (Minutes)					
	10 meters			100 meters		
	1 Person	2 Persons	3 Persons	1 Person	2 Persons	3 Persons
			Fiber Optic System			
1	5	3	3	18	6	5
2	4	3	5	17	11	5
3	4	4	3	17	11	6
4	4	3	--	12	11	--
5	4	3	--	8	10	--
6	4	3	--	10	12	--
			Metallic Cable System			
1	4	2	2	7	5	5
2	5	3	3	3	4	5
3	4	5	2	4	10	4
4	5	3	--	3	4	--
5	5	3	--	4	5	--
6	4	2	--	5	5	--

TABLE XIV. RECOVERY TIME

	Recovery Time (Minutes)					
	10 meters			100 meters		
Trial Number	1 Person	2 Persons	3 Persons	1 Person	2 Persons	3 Persons
			Fiber Optic System			
1	3	3	2	16	7	6
2	3	2	2	12	10	5
3	3	2	3	10	10	5
4	3	2	--	10	9	--
5	2	2	--	11	10	--
6	2	2	--	10	10	--
			Metallic Cable System			
1	2	1.5	2	3	5	4
2	3	2	2	11	5	3
3	3	2	1.5	11	4	4
4	5	1.5	--	6	3	--
5	2	2	--	5	4	--
6	2	1.5	--	5	3	--

3. 12.6 MHZ ANALOG LINK

3.1 IDLE CHANNEL NOISE

A. Equipment Used.

1. Fiber Optic System.

a. 12.6 Mbs analog fiber optic modems (4 ea).

b. Fiber optic cable (10- and 100-meter lengths).

c. TSEC/CY-104 multiplexer (HY-12A, SN 139 and HN-74, SN 500).

d. AN/FCC-97 multiplexer (SN 01J0033).

e. Transmission impairment measurement set (HP-4940A TIMS, SN 01A00688).

f. AN/FRC-162 M/W radio, SN 31A.

g. TerriCom M/W radio, NSN.

2. Metallic Cable System.

a. Coax cable RG-59 (10- and 100-meter lengths).

b. TSEC/CY-104 multiplexer (HY-12A, SN 139 and HN-74, SN 500).

c. AN/FCC-97 multiplexer (SN 01J0033).

d. Transmission impairment measuring set (HP-4940A TIMS, SN 01A00688).

e. AN/FRC-162 M/W radio, SN 31A.

f. TerriCom M/W radio, NSN.

B. Procedure.

1. TSEC/CY-104 Loop Back (NRZ Loop J107 to J108).

a. Test set up using figure 8.

b. HP-4940A TIMS was set up in the following manner. Switches were set for message circuit noise, noise filter selection to C-message weighting, and circuit impedance of 600 ohms. The transmit channel of the TSEC/CY-104 was terminated at 600 ohms. The noise level was checked at the front receiver patch on the 7120-05 channel unit card of the TSEC/CY-104.

2. Fiber Optic System -- Same procedure as in B.1 above except using figure 20.

3. Metallic Cable System -- Same procedure as in B.1 above except using figure 21.

C. Test Data.

TABLE XV. IDLE CHANNEL NOISE OF 12.6 MBS FIBER OPTIC SYSTEM

Channel Tested (No.)	Idle Channel Noise (dBrnc)			
	TSEC/CY-104 Looped Back	10-meter Fiber Optic Cable	TSEC/CY-104 Looped Back	100-meter Fiber Optic Cable
3	22	23	23	24
7	18	20	18	20
10	23	23	22	23
15	23	23	23	24
19	23	24	23	24
22	18	19	18	20

TABLE XVI. IDLE CHANNEL NOISE OF 12.6 MBS METALLIC CABLE SYSTEM

Channel Tested (No.)	Idle Channel Noise (dBrnc)			
	TSEC/CY-104 Looped Back	10-meter Coax Cable	TSEC/CY-104 Looped Back	100-meter Coax Cable
3	22	22	22	22
7	17	19	17	19
10	23	23	24	24
15	24	24	24	24
19	24	24	24	24
22	18	18	18	18

3.2 CROSSTALK

A. Equipment Used.

1. Fiber Optic System.

a. Fiber optic modems (4 ea).

b. Fiber optic cable (10- and 100-meter lengths).

c. TSEC/CY-104 multiplexer (HY-12A, SN 139 and HN-74, SN 500).

d. AN/FCC-97 multiplexer (SN 01J0033).

e. Transmission impairment measurement set (HP-4940A TIMS, SN 01A00688).

f. Test oscillator (HP-204C SN 808-01789).

g. AN/FRC-162 M/W radio, SN 31A.

h. TerriCom M/W radio, NSN.

2. Metallic Cable System.

a. Coax cable RG-59 (10- and 100-meter lengths).

b. TSEC/CY-104 multiplexer (HY-12A, SN 139 and HN-74, SN 500).

c. AN/FCC-97 multiplexer (SN 01J0033).

d. Transmission impairment measuring set (HP-4940A TIMS, SN 01A00683).

e. Test oscillator (HP-204C, SN 808-01789).

f. AN/FRC-162 M/W radio, SN 31A.

g. TerriCom M/W radio, NSN.

B. Procedure.

1. Fiber Optic System.

a. Test set up using figure 22.

b. HP-204C test oscillator was set at 1000 Hz and a -16 dBm tone was inserted into the transmit patch on the 7120-05 channel unit card of the TSEC/CY-104. The receive patch of the disturbing channel was terminated at 600 ohms. The HP-4940A TIMS was set up in the following manner. Switches were set for message circuit noise, noise filter selection to C-message weighting, and circuit impedance of 600 ohms. The TIMS was then connected to the receive patch of the 7120-05 channel unit card of the disturbed channel. The transmit patch of the 7120-05 channel unit card was terminated at 600 ohms. The tone was inserted on channels 2 and 23, and the physically and electrically adjacent channels to both were tested.

2. Metallic Cable System -- Same procedure as in B.1 above except using figure 23.

C. Test Data.

TABLE XVII. CROSSTALK MEASUREMENT, 12.6 MBS ANALOG LINK (-16 DBM TONE INSERTED ON CHANNEL 2)

Channel	Fiber Optic System				Metallic Cable System			
	10-meter		100-meter		10-meter		100-meter	
Measured (No.)	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)
1	22	23	22	22	22	23	22	22
3	22	22	22	22	22	23	21	22
14	23	23	23	23	23	23	23	24
18	24	24	24	24	24	24	24	24

TABLE XVIII. CROSSTALK MEASUREMENT, 12.6 MBS ANALOG LINK (-16 DBM TONE INSERTED ON CHANNEL 23)

Channel	Fiber Optic System				Metallic Cable System			
	10-meter		100-meter		10-meter		100-meter	
Measured (No.)	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)	ICN (dBrnc)	Crosstalk (dBrnc)
7	21	21	21	21	21	21	20	20
11	21	21	21	21	21	21	21	21
22	20	20	20	20	20	21	20	20
24	17	17	17	17	17	17	18	18

3.3 DISTORTION

A. Equipment Used.

1. Fiber Optic System.

   a. Fiber optic modems (4 ea).

   b. Fiber optic cables (10- and 100-meter lengths).

   c. BAMI/TTL interface converter (2 ea, SN 002604 and 002605).

   d. TSEC/CY-104 multiplexer (HY-12A, SN 139 and HN-74, SN 500).

   e. AN/FCC-97 multiplexer (SN 01J0033).

   f. Balanced to unbalanced circuit transformer.

   g. Test oscillator (HP-204C, SN 808-01789).

   h. Frequency selective voltmeter (Rycom 6010, SN 122).

   i. Distortion analyzer (HP-334A, SN 1140A07152).

   j. AN/FRC-162 M/W radio, SN 31A.

   k. TerriCom M/W radio, NSN.

2. Metallic Cable System.

   a. Coax cable RG-59 (10- and 100-meter lengths).

   b. TSEC/CY-104 multiplexer (HY-12A, SN 139 and HN-74, SN 500).

   c. AN/FCC-97 multiplexer (SN 01J0033).

   d. Balanced to unbalanced circuit transformer.

   e. Test oscillator (HP-204C, SN 808-01789).

   f. Frequency selective voltmeter (Rycom 6010, SN 122).

   g. Distortion analyzer (HP-334A, SN 1140A07152).

   h. AN/FRC-162 M/W radio, SN 31A.

   i. TerriCom M/W radio, NSN.

B. Procedure.

1. Baseline Measurement.

a. Test set up using figure 5.

b. Test oscillator HP-204C was set at 1000 Hz and -16 dBm, connected to the balanced side of the transformer and was terminated at 600 ohms impedance. The distortion analyzer HP-334A was connected to the unbalanced side of the transformer and measurements taken. The procedure was then repeated for 2000 Hz and 3000 Hz. Coax cable length between transformer and distortion analyzer was then varied, using 1-, 10-, and 100-meter lengths.

2. Distortion Measurement of HY-12A.

a. Test set up using figure 13.

b. The test oscillator HP-204C was set at 1000 Hz and inserted a -16 dBm tone into the transmit patch on the 7120-05 channel unit card of the HY-12A. The receive patch on the 7120-05 channel unit card was then connected to the balanced side of the transformer and terminated at 600 ohms. The frequency selective voltmeter Rycom 6010, set at 600 ohms bridging, was also connected to the balanced side of the transformer. The distortion analyzer HP-334A was connected to the unbalanced side of the transformer. The frequency selective voltmeter was tuned to 1000 Hz and output of the test oscillator adjusted until proper signal levels were observed. Distortion measurements were then taken. This procedure was repeated for 2000 Hz and 3000 Hz. Both channels 2 and 23 were measured.

3. Fiber Optic System -- Same procedure as B.2 above except using figure 24.

4. Metallic Cable System -- Same procedure as B.2 above except using figure 25.

C. Test Data.

TABLE XIX. DISTORTION MEASUREMENT AT 12.6 MBS ANALOG LINK BASELINE READINGS

Test Tone Frequency (Hz)	Distortion (%)		
	1 meter	10 meters	100 meters
1000	0.072	0.072	0.072
2000	0.046	0.052	0.052
3000	0.038	0.046	0.048

TABLE XX. DISTORTION MEASUREMENT (12.6 MBS ANALOG LINK)

Channel (No.)	Frequency (Hz)	Distortion (%)				
		HY-12A	Fiber Optic System 10 meters	Fiber Optic System 100 meters	Metallic Cable System 10 meters	Metallic Cable System 100 meters
2	1000	1.95	1.95	1.95	1.95	1.95
	2000	1.90	1.90	1.90	1.90	1.90
	3000	2.70	2.70	2.70	2.70	2.70
23	1000	2.00	2.00	2.00	2.00	2.00
	2000	2.00	2.00	2.00	2.00	2.00
	3000	2.90	2.90	2.90	2.90	2.90

3.4 BIT ERROR RATE

A. 10- and 100-Meter Fiber Optic Cable System.

1. Equipment Used.

a. HP-3780A pattern generator/error detector, SN 1739N00477.

b. AN/FRC-162 radio, SN 31A.

c. TerriCom M/W radio, NSN.

d. ITT 1503 fiber optic modem transmitter.

e. ITT 1608 fiber optic modem receiver.

f. 10- and 100-meter fiber optic cable.

2. Procedure. HP-3780A set up for code output PRBS N=15. HP-3780A receiver set up for code input (see fig 26).

B. 10- and 100-Meter Coax System.

1. Equipment Used.

a. HP-3780A pattern generator/error detector, SN 1739N00477.

b. AN/FRC-162 radio, SN 31A.

c. TerriCom M/W radio, NSN.

d. 10- and 100-meter coax cable.

2. Procedure. HP-3780A set for code output PRBS N=15. HP-3780A receiver set for code input PRBS. Bit rate was 12.928 Mbs (see fig. 27).

C. Test Data.

TABLE XXI. BIT ERROR COUNT (12.6 MBS LINK) (16/32 KBS CDP TEST)

Input Data Rate (kbs)	Number of Hours Test Was Run	Number of Errors			
		Fiber Optic Cable		Metallic Cable	
		10-meter	100-meter	10-meter	100-meter
16	100	0	0	0	0
32	50	0	0	0	0

3.5 CONNECT/DISCONNECT

A. Equipment Used.

1. Fiber Optic System.

a. Fiber optic modems (4 ea).

b. Fiber optic cable (10-meter length).

c. BAMI/TTL interface converter (2 ea, SN 002604 and 002605).

d. TSEC/CY-104 multiplexer (HY-12A, SN 139 and HN-74, SN 500).

e. AN/FCC-97 multiplexer (SN 01J0033).

f. Transmission impairment measurement set (HP-4940A TIMS, SN 01A00688).

g. AN/FRC-162 M/W radio, SN 31A.

h. TerriCom M/W radio, NSN.

2. Metallic Cable System.

a. Coax cable RG-59 (10-meter length).

b. TSEC/CY-104 multiplexer (HY-12A, SN 139 and HN-74, SN 500).

c. AN/FCC-97 multiplexer (SN 01J0033).

d. Transmission impairment measuring set (HP 4940A TIMS, SN 01A00688).

e. AN/FRC-162 M/W radio, SN 31A.

f. TerriCom M/W radio, NSN.

B. Procedure.

1. Fiber Optic System.

a. Test set up using figure 20.

b. The fiber optic cable between the two optical modems carrying data was disconnected and reconnected 100 times. Idle channel noise was measured every 10 times.

2. Metallic Cable System.

a. Test set up using figure 21.

b. The coax cable between the TSEC/CY-104 and the AN/FCC-97 was disconnected and reconnected 100 times. Idle channel noise was measured every 10 times.

C. Test Data.

TABLE XXII. CONNECT/DISCONNECT TEST (12.6 MBS ANALOG)
(ICN IN DBRNC OF CHANNEL 2)

Number of Connects/Disconnects	Idle Channel Noise (dBrnc)	
	Fiber Optic	Metallic
0	23	23
10	23	23
20	23	23
30	23	23
40	23	23
50	23	23
60	23	23
70	23	23
80	23	23
90	23	23
100	23	23

3.6 CYCLIC FLEXING

A. Equipment Used on Fiber Optic System.

1. Optical modem.

2. Fiber optic cable (10-meter length).

3. Frequency synthesizer (SYNTEST SI-102, SN 10-2039).

4. Optical power meter (United Detector Technology, Mdl 40X, SN 46088).

B. Procedure.

1. Test set up using figure 17.

2. The frequency synthesizer was set at 1 MHz, 1-volt peak-to-peak square wave. The output was inserted into the optical modem. Optical power output was measured with the optical power meter. The cable was flexed over a mandrel 2.5 times the diameter of the cable. Power readings at the end of the cable were measured every 100 cycles.

3. Test set up using figure 28 for metallic cable.

4. Ten meters of coax were subjected to flexing measurements as per B.2 above

C. Test Data.

TABLE XXIII. CYCLIC FLEX TEST (12.6 MBS) FOR FIBER OPTIC CABLE

Number of Cycles	Optical Power (uW)	Number of Cycles	Optical Power (uW)
0	10	600	10
100	10	700	10
200	10	800	10
300	10	900	10
400	10	1000	10
500	10		

TABLE XXIV. CYCLIC FLEX TEST FOR COAX CABLE

Number of Flex Cycles	Voltage Measured (volts peak-to-peak)
0	1
10	1
20	1
30	1
40	1
50	1
60	1
70	1
80	1
90	1
100	1

(31)

Figure # 1

4 Khz Fiber Optic System Idle channel Noise

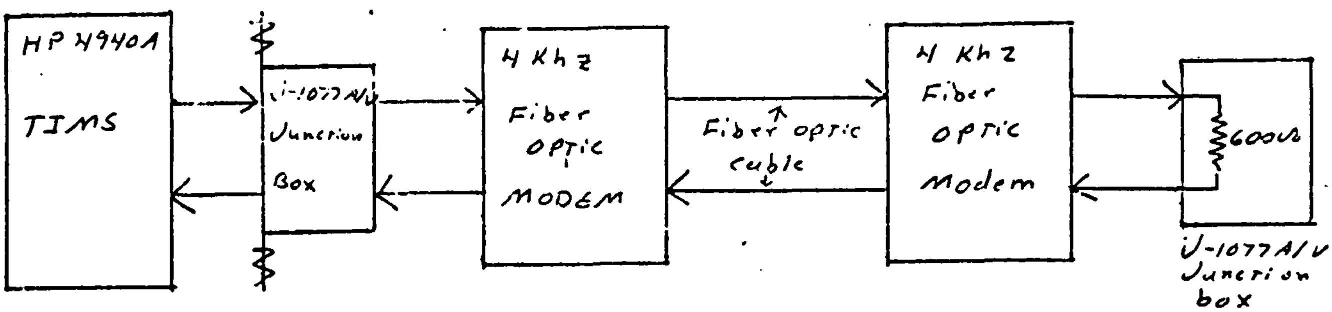


Figure # 2

4 Khz metallic Cable System Idle Channel Noise

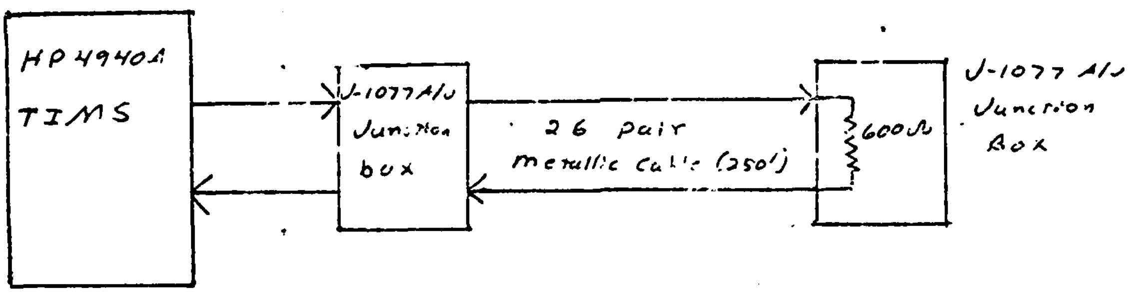


Figure # 3

4 Khz Fiber Optic System CROSSTALK

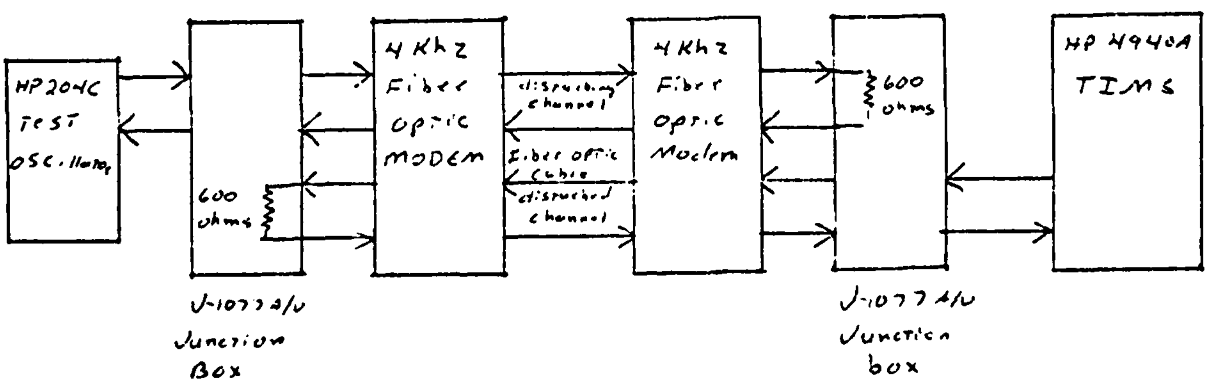


Figure # 4

4 Khz Metallic Cable System CROSSTALK

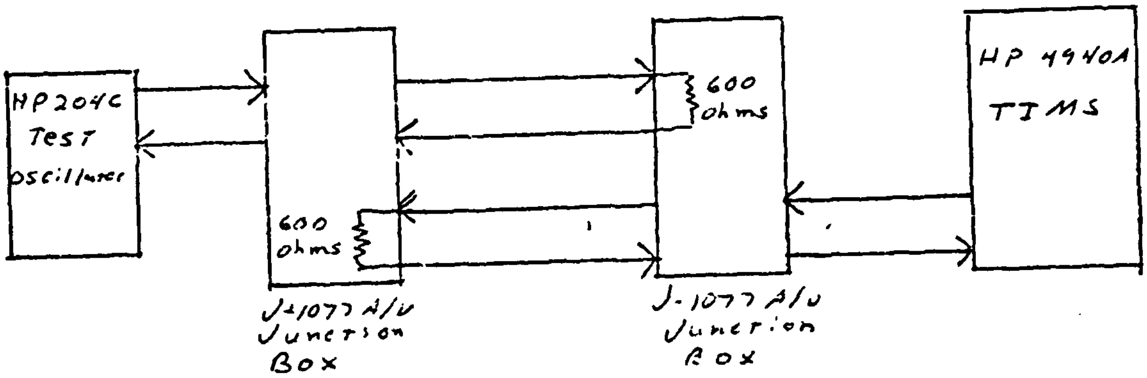


Figure # 5

Base line Measurement Distortion

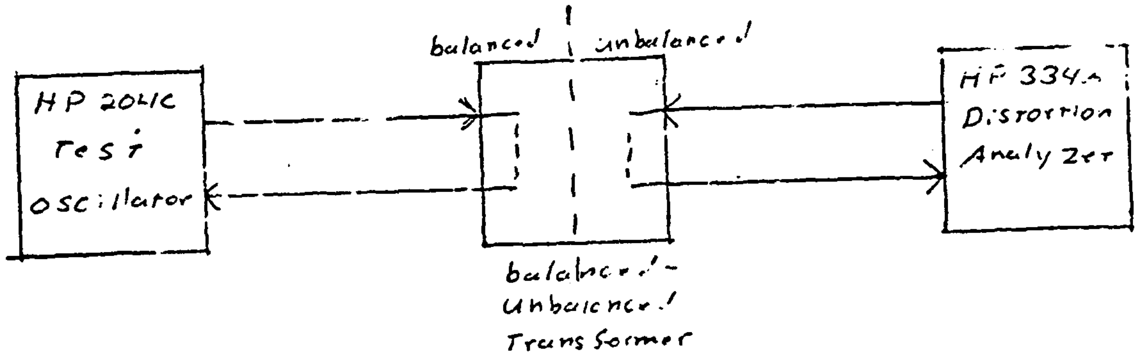


Figure # 6

4 Khz Fiber optic System Distortion

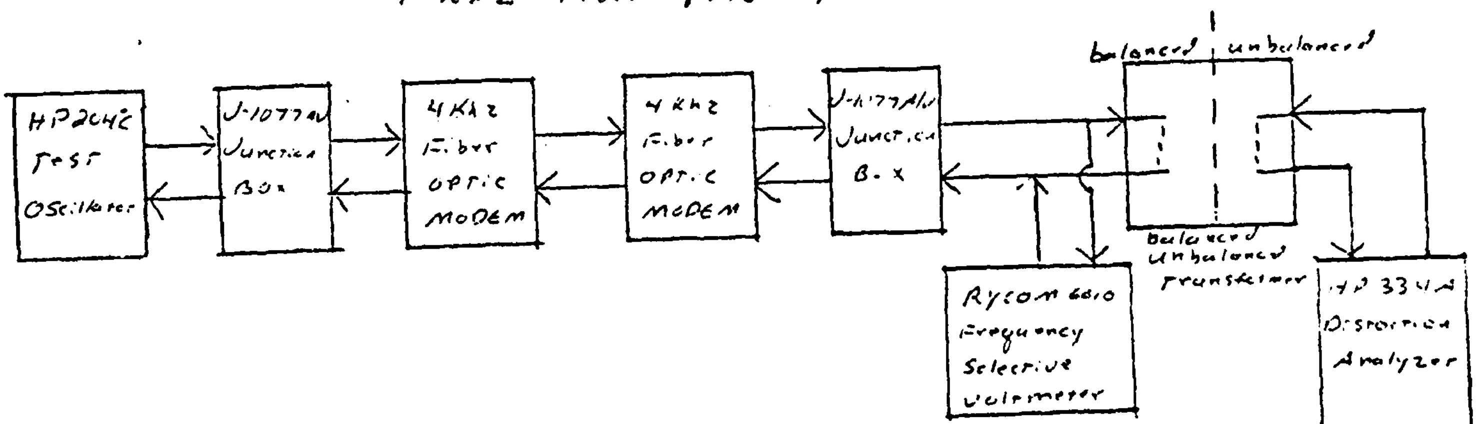


Figure #7

4 Khz Metallic Cable System Distortion

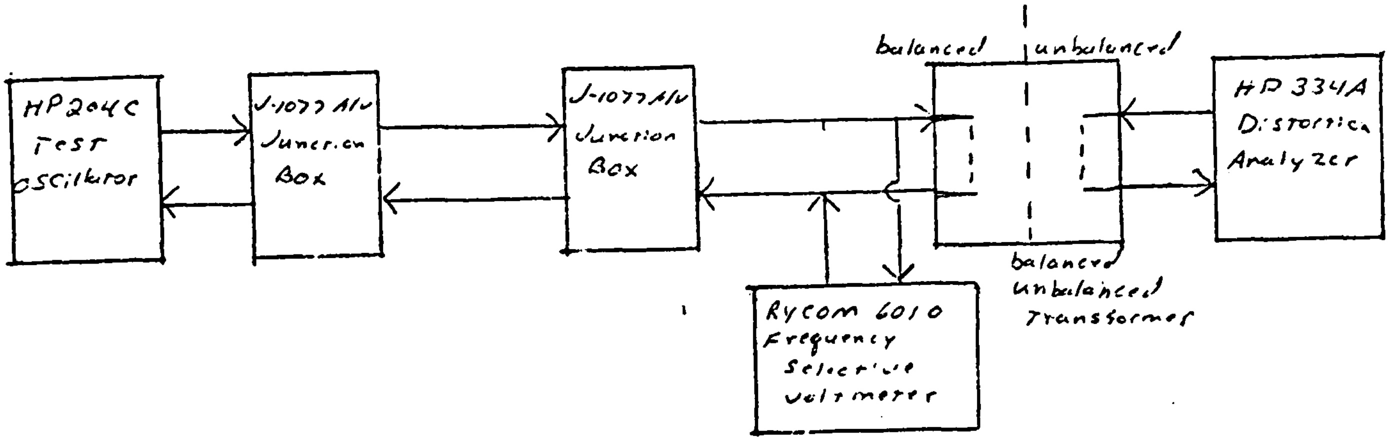


Figure #8

1.544 Mbs Data TSEC/CY-104 Loop Back

NRZ Loop J107 to J108

Idle Channel Noise

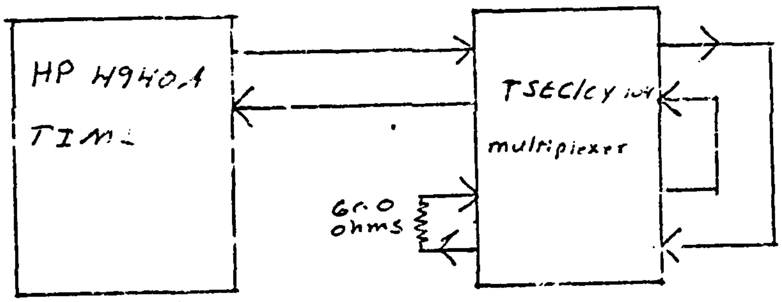


Figure #9

1.544 Mbs Data Fiber Optic System

Idle channel noise

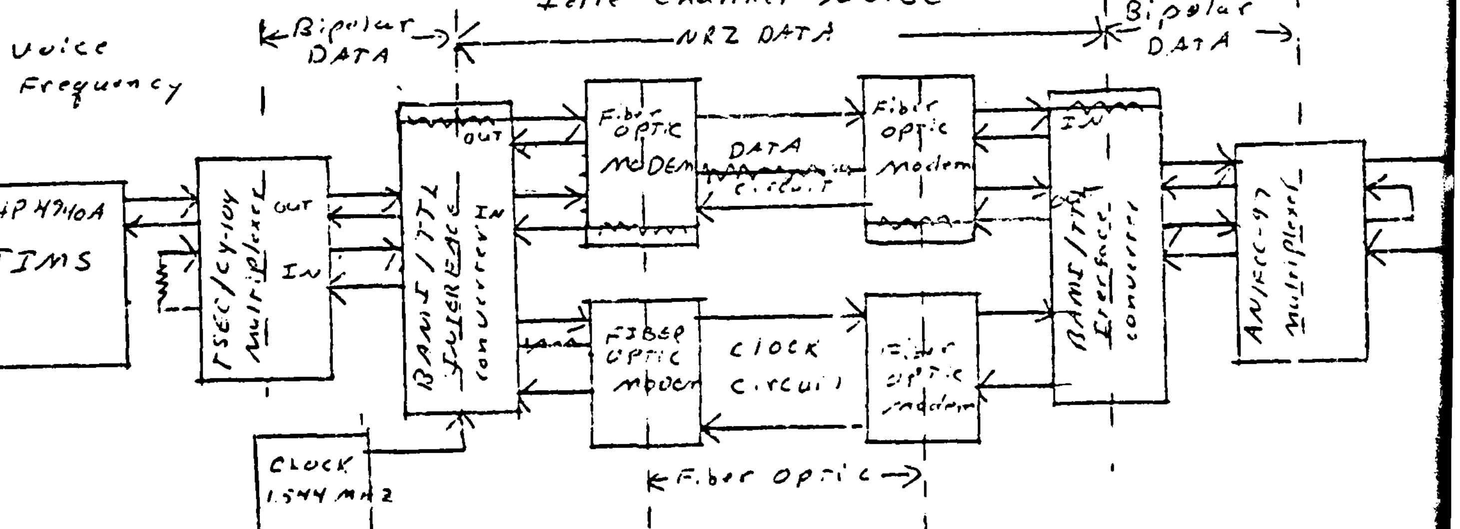


Figure # 10
1.544 Mbs Data Metallic Cable System
IDLE Channel Noise

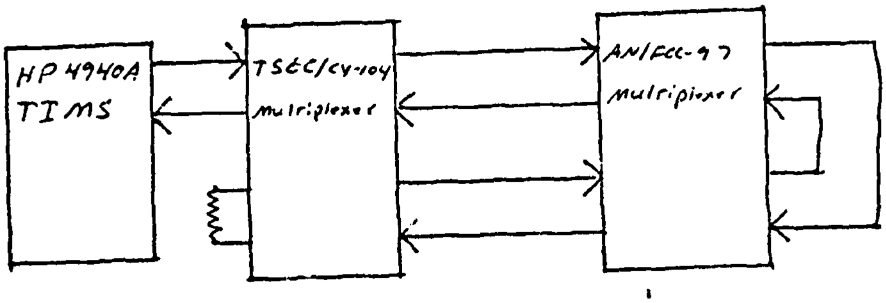


Figure # 11
1.544 Mbs Data Fiber optic System
CROSSTALK

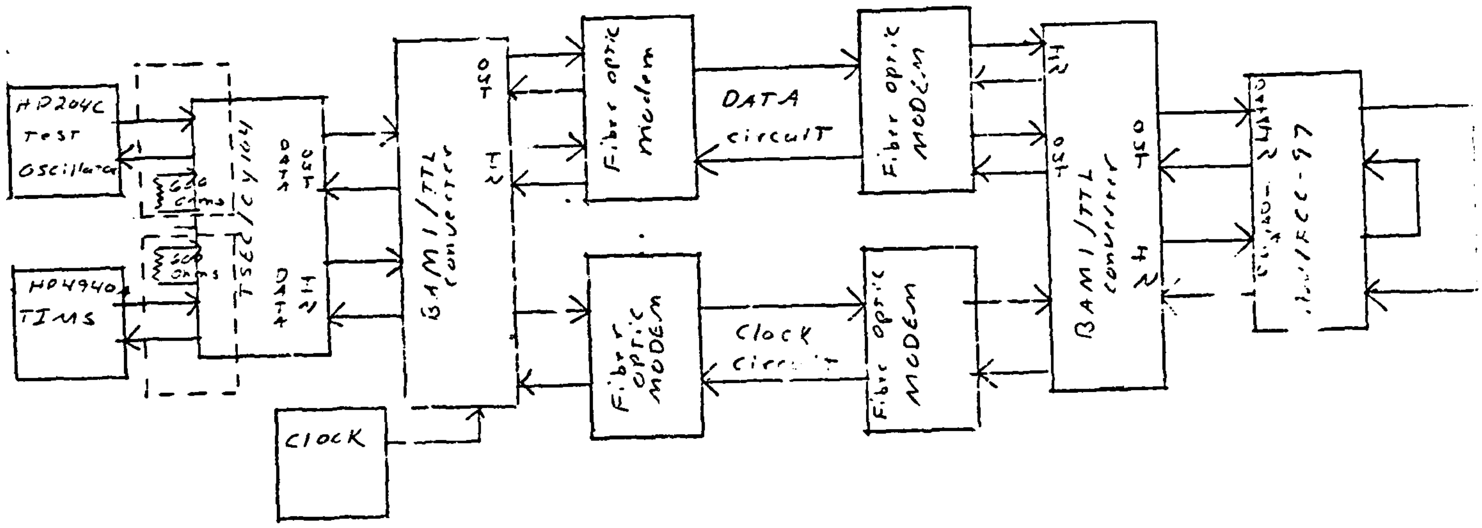
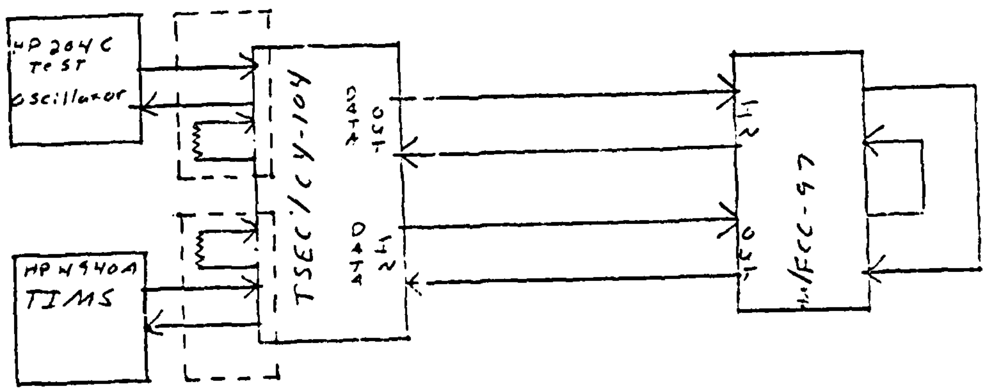


Figure # 12
1.544 Mbs Data Metallic Cable System
CROSSTALK



(35)

Figure #13
Distortion of HY-12A

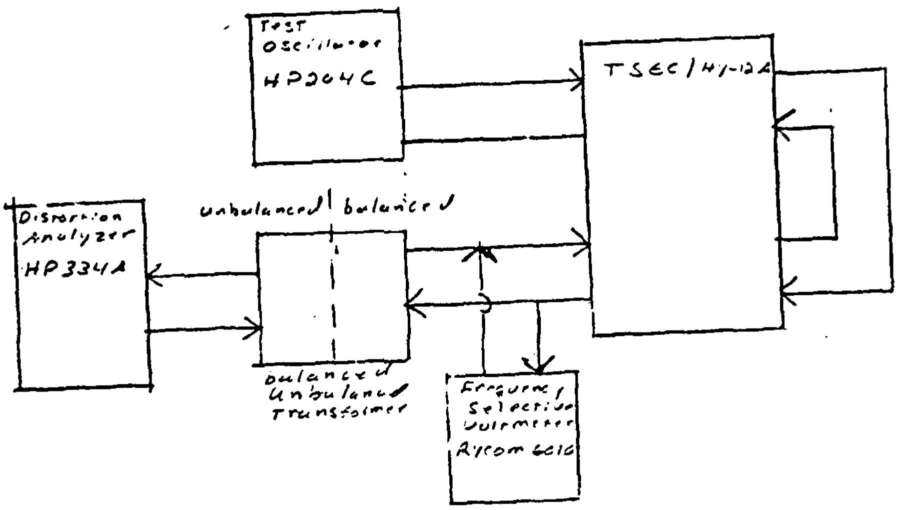


Figure # 14
Distortion
1.544 Mbs Data
Fiber Optic System

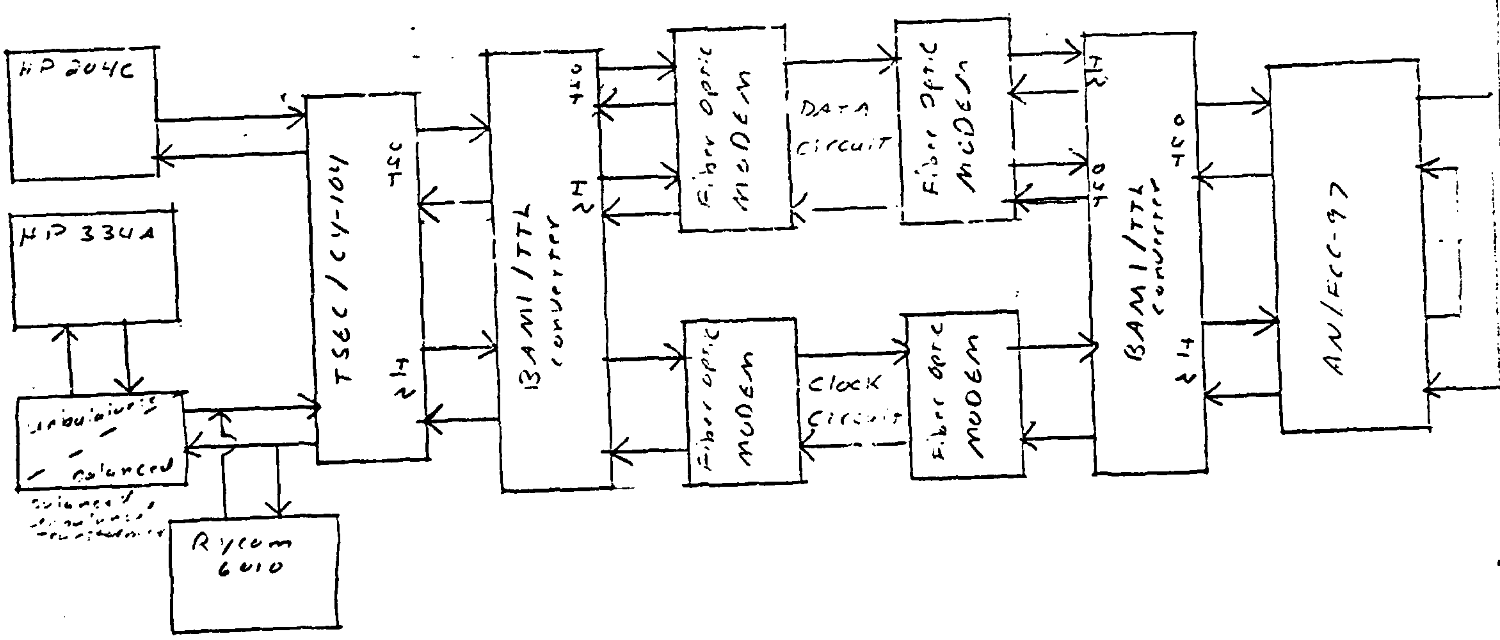


Figure #15
1.544 Mbs ~~[illegible]~~ Data Metallic Cable System
Distortion

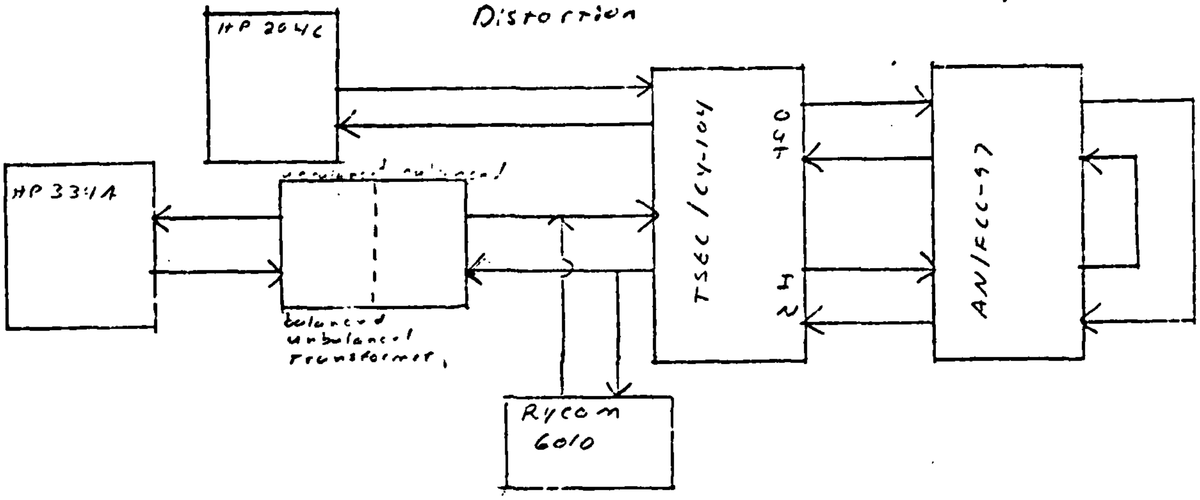


Figure #16
Conditione Diphase Pattern Test

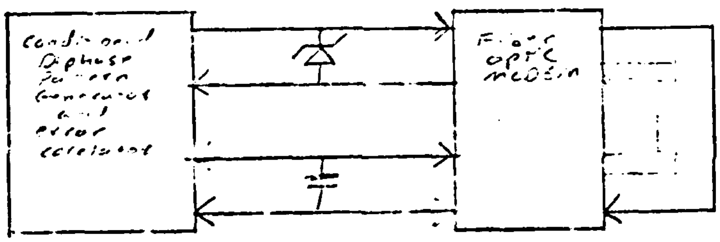
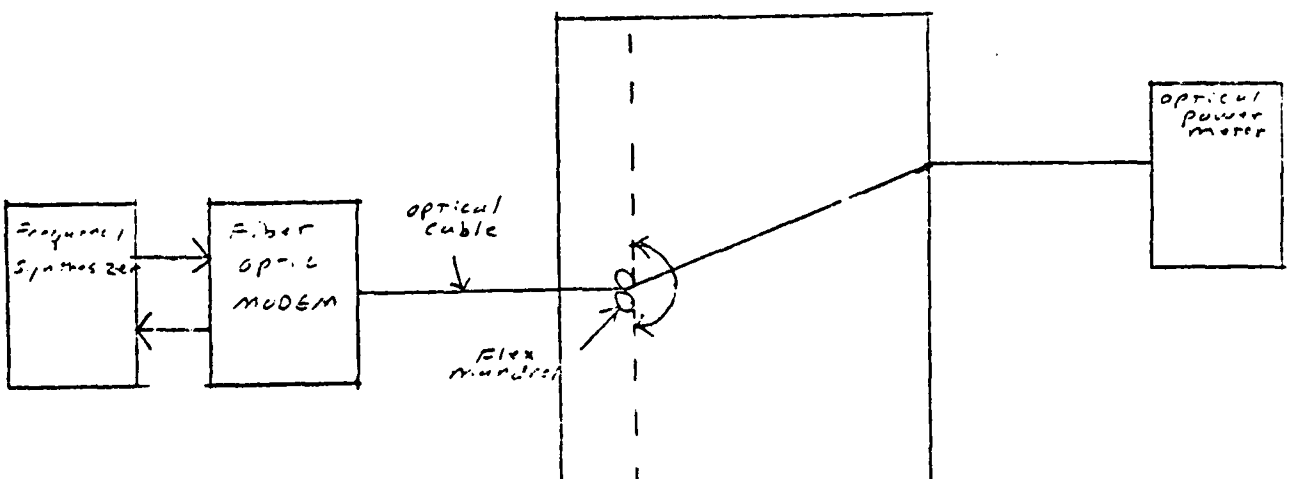


Figure #17
Cyclic Flex Test



(37)

Figure 18
INSTALLATION/RECOVERY
1.544Mbs Fiber Optic System

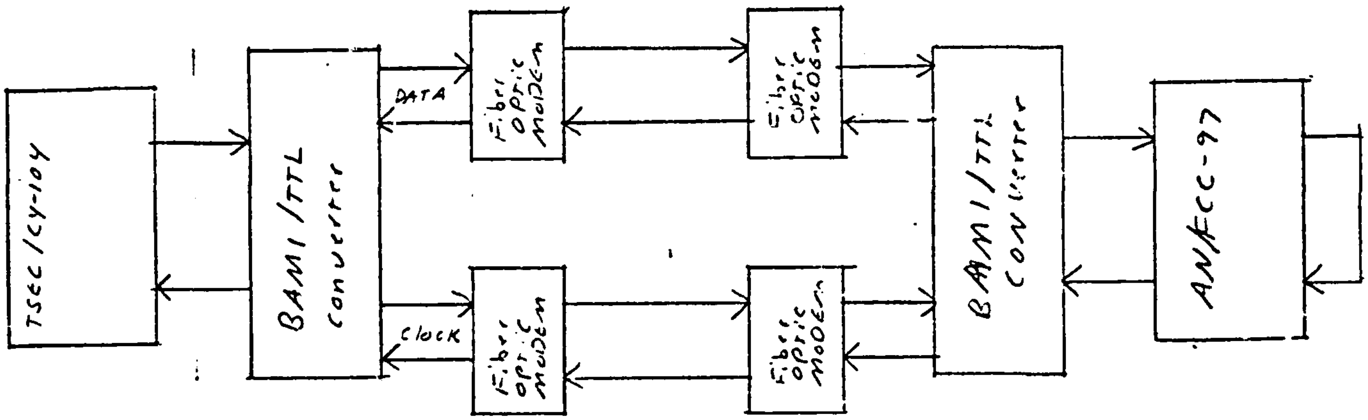


Figure 19
INSTALLATION / Recovery
1.544Mbs Metallic Cable System

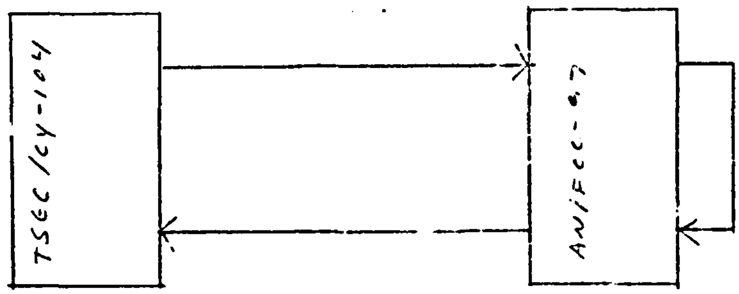


Figure # 20
IDLE Channel Noise
12.6 MHz Fiber optic System

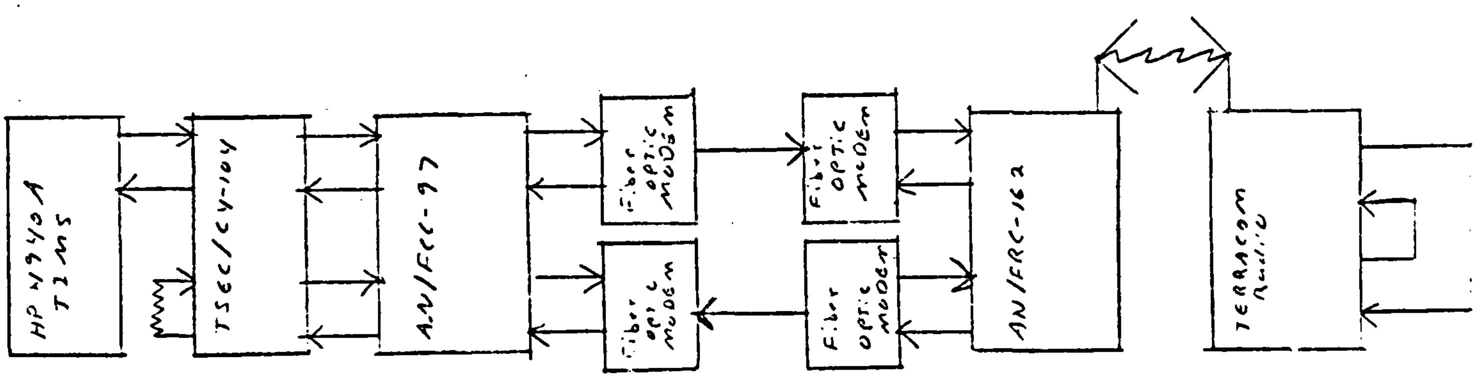


Figure 21
12.6 MHZ Metallic Cable System
ICN

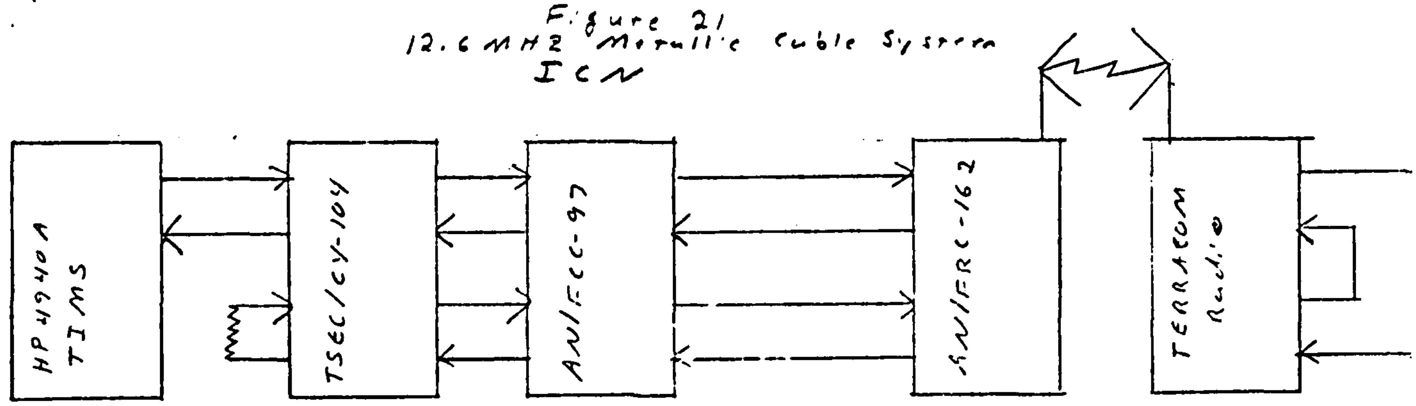


Figure #22
12.6 MHZ Fiber Optic Cable System
CROSSTAlK

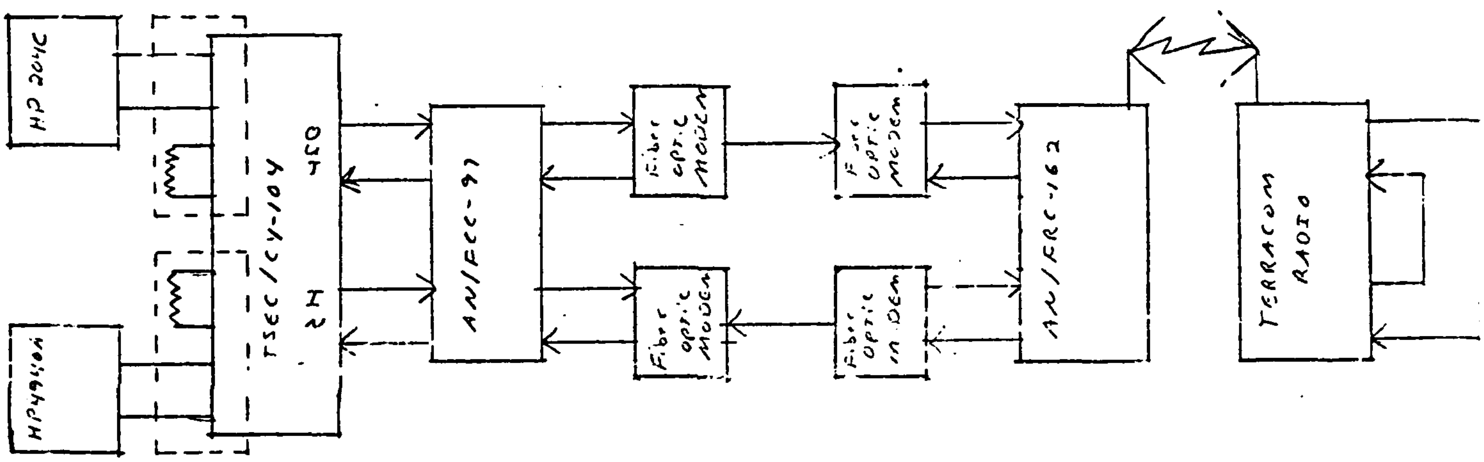


Figure #23
12.6 MHZ Metallic Cable System
CROSSTAlK

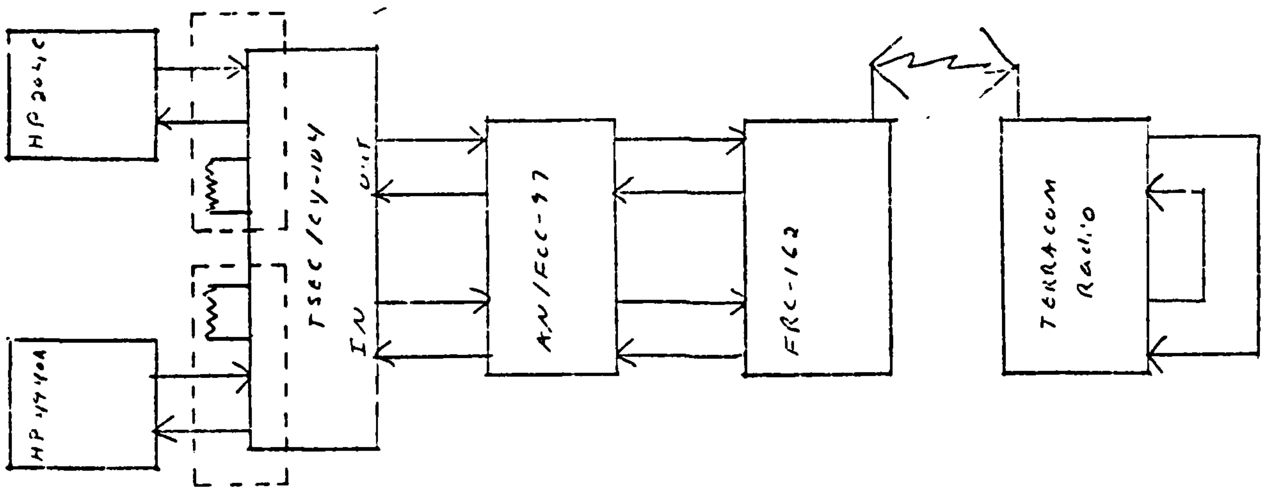


Figure 24

12.6 MHz Fiber Optic System Distortion

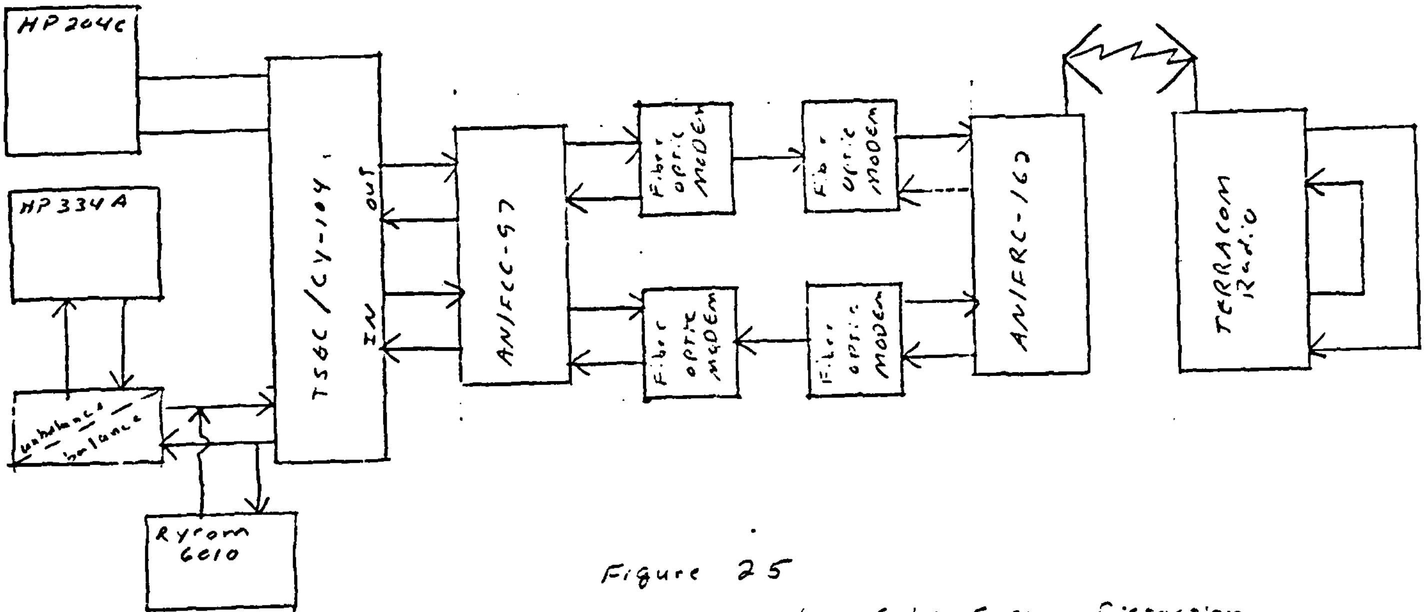


Figure 25

12.6 MHZ Metallic Cable System Distortion

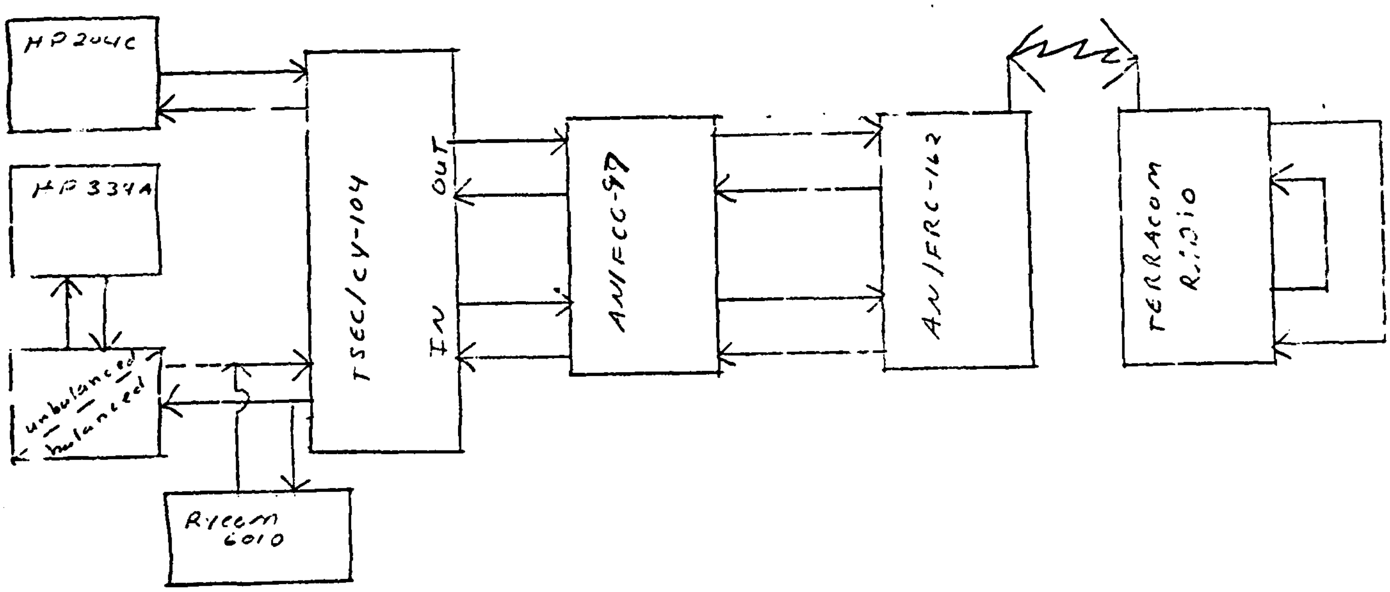


Figure 26

12.6 MHz Fiber Optic Cable Bit ERROR Rate TEST

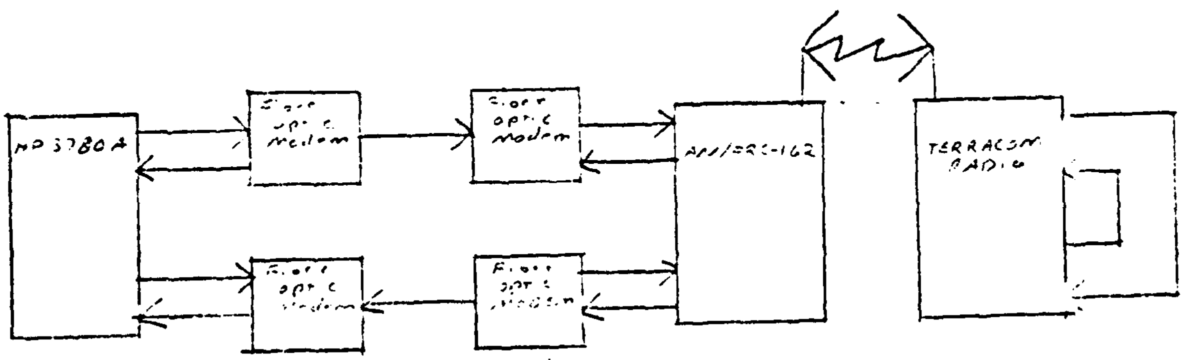


Figure 27
12.6 MHz METALLIC CABLE SYSTEM BIT ERROR RATE TEST

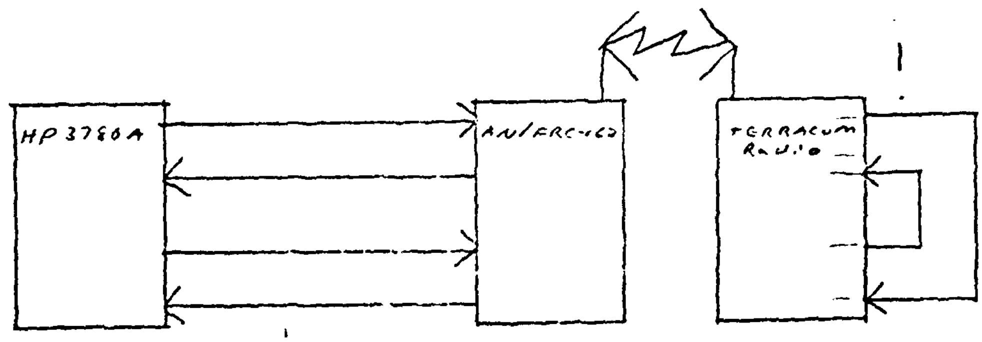
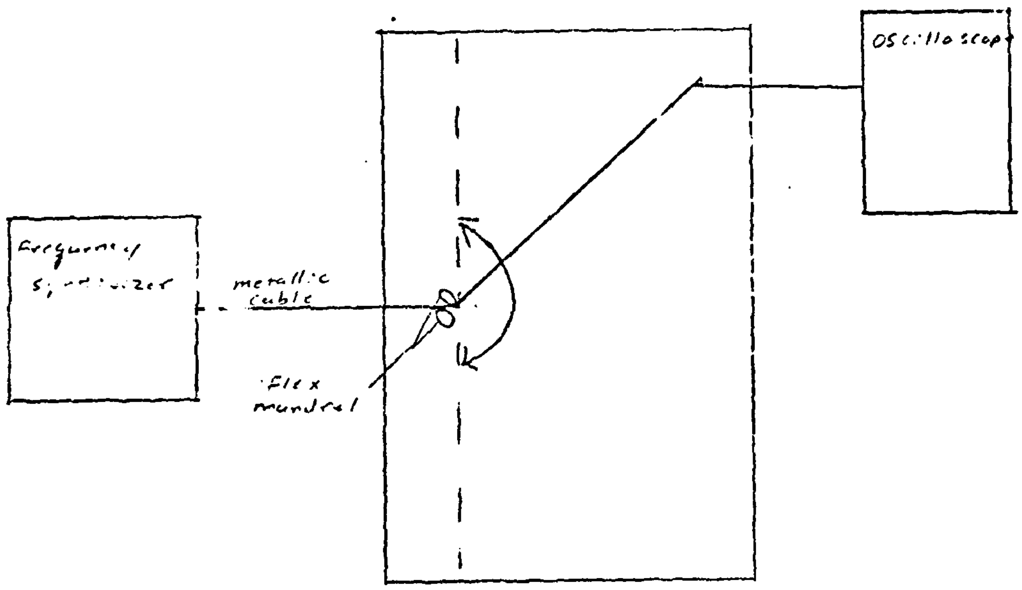


Figure 28
Metallic Cable ~~Sys~~ Link Cyclic Flex test



APPENDIX B

SUPPLEMENTAL TESTING

AND

TEST RESULTS

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

1. FREQUENCY RESPONSE - 4 kHz FIBER OPTIC SYSTEM

a. Equipment Used

(1) HP Oscillator 204C, SN 808-01789

(2) Rycom Selective Voltmeter 6010, SN 121

(3) Junction Box J-1077A (2 each)

(4) Harris 4 kHz Modem, SN 001, 002

(5) Fiber Optic Cable (300 meters)

b. Data Acquisition Procedure

(1) The test equipment was connected as shown in figure 5. The oscillator (OSC) input was set for -10 dBm (power) at a frequency of 200 Hz; it was routed through channel 9 of the "XMIT" modem (SN 001), the fiber optic cable, channel 9 of the "RCVR" modem (SN 002), to the voltmeter. The voltmeter was set for a 600-ohm terminating impedance and tuned to measure the output of the "RCVR" modem at 200 Hz. A reading from the voltmeter was recorded.

(2) The OSC and voltmeter were adjusted at 100 Hz steps from 200 Hz to 4 kHz. Output readings were recorded at each frequency setting.

(3) The modems were interchanged, with SN 002 as the "XMIT" modem and SN 001 as the "RCVR" modem. The procedure shown in subparagraphs B1 and B2 was repeated.

(4) The procedures shown in subparagraphs B1-B3 were repeated using channel 11 of each modem.

c. Test Data

(1) The frequency response of channel 9 of the system, with "XMIT" modem SN 001 and "RCVR" modem SN 002, is shown in table I and figure 1. The absolute output level at 1 kHz was -11.7 dBm.

(2) The frequency response of channel 9 of the system, with "XMIT" modem SN 002 and "RCVR" modem SN 001, is shown in table II and figure 1. The absolute output level at 1 kHz was -10.5 dBm.

(3) The frequency response of channel 11 of the system, with "XMIT" modem SN 001 and "RCVR" modem SN 002, is shown in table III and figure 2. The absolute output level at 1 kHz was -13.5 dBm.

(4) The frequency response of channel 11 of the system, with "XMIT" modem SN 002 and "RCVR" modem SN 001, is shown in table IV and figure 2. The absolute output level at 1 kHz was -10.7 dBm.

(5) During testing, it was noted that the cable for the optical connection between the modems did not seat well. Movement was capable of changing output by up to 6 dB.

TABLE I. FREQUENCY RESPONSE OF CHANNEL 9 OF 4 kHz FIBER OPTIC SYSTEM WITH "XMIT" MODEM SN 001 AND "RCVR" MODEM SN 002

FREQ (kHz)	LOSS (dB)	FREQ (kHz)	LOSS (dB)
0.2	0.2	2.1	3.3
0.3	0.4	2.2	3.5
0.4	1.0	2.3	3.6
0.5	1.5	2.4	3.8
0.6	1.5	2.5	3.9
0.7	2.0	2.6	4.0
0.8	2.0	2.7	4.2
0.9	2.3	2.8	4.4
1.0	1.7	2.9	4.5
1.1	1.8	3.0	4.5
1.2	1.9	3.1	4.7
1.3	2.0	3.2	5.0
1.4	2.3	3.3	5.1
1.5	2.5	3.4	5.3
1.6	3.2	3.5	5.5
1.7	2.4	3.6	5.6
1.8	2.7	3.7	6.0
1.9	3.0	3.8	6.0
2.0	3.0	3.9	6.1
		4.0	6.2

TABLE II. FREQUENCY RESPONSE OF CHANNEL 9 OF 4 kHz FIBER OPTIC SYSTEM WITH "XMIT" MODEM SN 002 AND "RCVR" MODEM SN 001

FREQ (kHz)	LOSS (dB)	FREQ (kHz)	LOSS (dB)
0.2	-2.0	2.1	2.2
0.3	-1.0	2.2	2.2
0.4	-0.5	2.3	2.4
0.5	0.0	2.4	2.5
0.6	0.0	2.5	2.7
0.7	0.2	2.6	3.0
0.8	0.3	2.7	3.1
0.9	0.3	2.8	3.3
1.0	0.5	2.9	3.5
1.1	0.8	3.0	3.6
1.2	1.0	3.1	3.8
1.3	1.0	3.2	4.0
1.4	1.2	3.3	4.1
1.5	1.3	3.4	4.3
1.6	1.5	3.5	4.4
1.7	1.5	3.6	4.6
1.8	1.7	3.7	4.7
1.9	1.8	3.8	4.9
2.0	2.0	3.9	5.0
		4.0	5.2

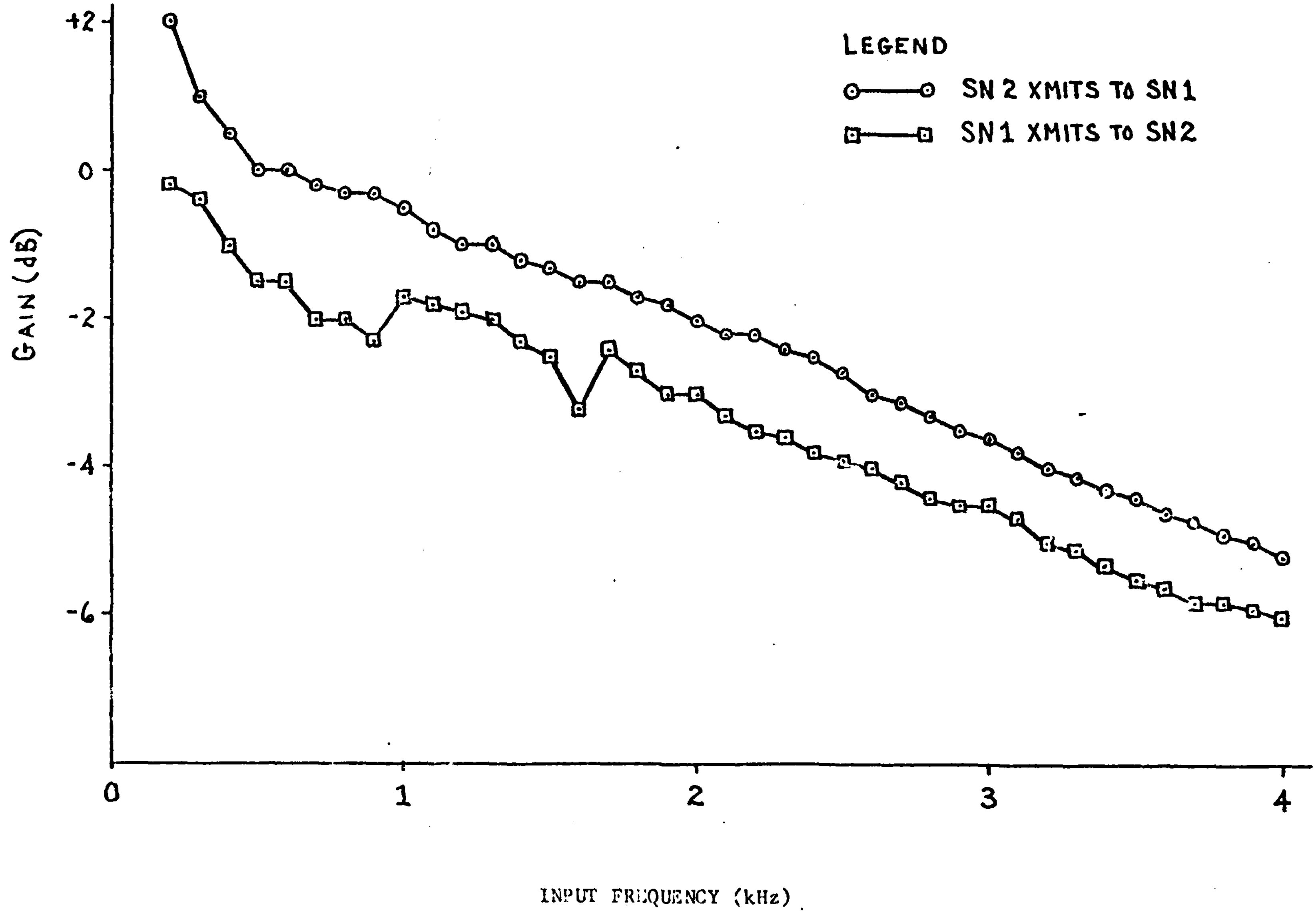


Figure 1. Frequency response of channel 9 of 4 kHz fiber optic system.

TABLE III. FREQUENCY RESPONSE OF CHANNEL 11 OF 4 kHz FIBER OPTIC SYSTEM USING "XMIT" MODEM SN 001 AND "RCVR" MODEM SN 002

FREQ (kHz)	LOSS (dB)	FREQ (kHz)	LOSS (dB)
0.2	4.0	2.1	3.8
0.3	4.7	2.2	4.0
0.4	4.9	2.3	4.1
0.5	4.8	2.4	4.4
0.6	4.5	2.5	4.4
0.7	4.0	2.6	4.5
0.8	3.7	2.7	4.6
0.9	3.5	2.8	4.7
1.0	3.5	2.9	5.0
1.1	3.5	3.0	5.0
1.2	3.4	3.1	5.2
1.3	3.4	3.2	5.4
1.4	3.4	3.3	5.5
1.5	3.4	3.4	5.6
1.6	3.5	3.5	5.8
1.7	3.5	3.6	6.0
1.8	3.5	3.7	6.1
1.9	3.6	3.8	6.3
2.0	3.7	3.9	6.5
		4.0	6.5

TABLE IV. FREQUENCY RESPONSE OF CHANNEL [illegible] OF 4 kHz FIBER OPTIC SYSTEM USING "XMIT" MODEM SN 002 AND "RCVR" MODEM SN 001

FREQ (kHz)	LOSS (dB)	FREQ (kHz)	LOSS (dB)
0.2	-0.1	2.1	1.7
0.3	1.0	2.2	1.8
0.4	0.9	2.3	2.0
0.5	0.8	2.4	2.1
0.6	0.8	2.5	2.4
0.7	0.7	2.6	2.5
0.8	0.7	2.7	2.5
0.9	0.7	2.8	2.6
1.0	0.7	2.9	2.8
1.1	0.7	3.0	3.0
1.2	0.8	3.1	3.1
1.3	0.9	3.2	3.3
1.4	0.9	3.3	3.5
1.5	1.0	3.4	3.5
1.6	1.1	3.5	3.6
1.7	1.2	3.6	3.8
1.8	1.4	3.7	3.8
1.9	1.5	3.8	3.0
2.0	1.6	3.9	3.2
		4.0	3.4

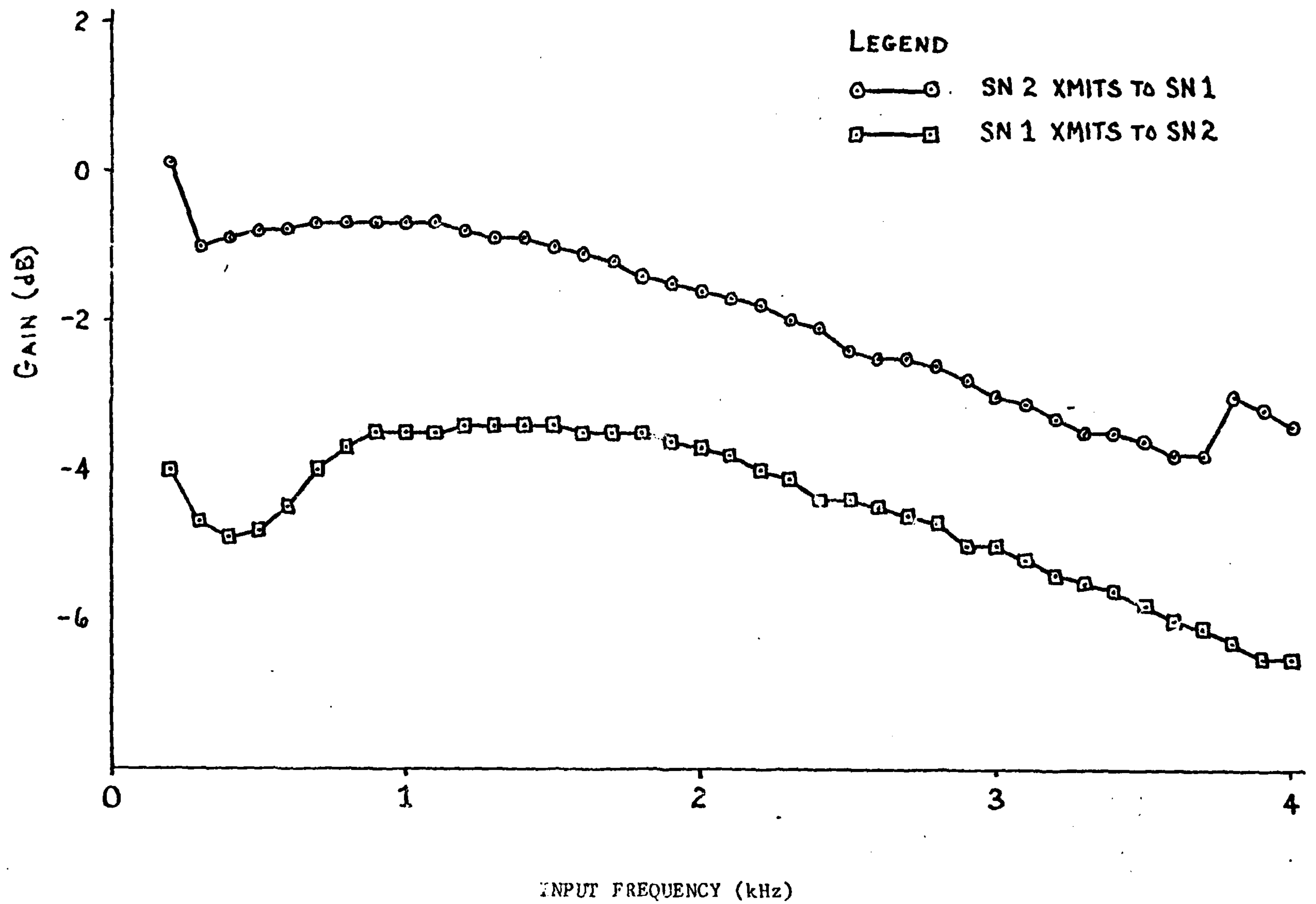


Figure 2. Frequency response of channel 11 of 4 kHz fiber optic system.

2. FREQUENCY RESPONSE.- 20 MHz FIBER OPTIC SYSTEM

a. Equipment Used

(1) HP Frequency Synthesizer 3320B, SN 32A01783

(2) HP Generator/Sweep 8601A, SN 12A04817

(3) HP Selective Voltmeter 312B, SN 34A00605

(4) ANRITSU Selective Voltmeter ML55C, SN M18114

(5) ITT Fiber Optic Modem T-608, SN 887, 888

(6) ITT Fiber Optic Modem T-603, SN 881, 884

(7) ITT Fiber Optic Cable (10 meters)

b. Data Acquisition Procedure

(1) The test equipment was connected as shown in figure 6, using T-603 modem SN 884 and T-608 modem SN 887. The 3320B OSC was set to input 0 dBm into the system at a frequency of 1 kHz. The 312B voltmeter was set for 75-ohms terminating impedance and 1 kHz. The output level was recorded.

(2) This procedure was repeated for frequencies from 1 to 9 kHz in 1 kHz steps from 10 to 100 kHz in 10 kHz steps, and from 1 to 10 MHz in 1 MHz steps. Output levels were recorded.

(3) The test equipment was connected as shown in figure 7, using the same modems iterated in subparagraph B1. The 312B generator was set to input 0 dBm into the system at a frequency of 10 MHz. The ML55C was set for 75-ohms terminating impedance and 10 MHz. The output level was recorded.

(4) This procedure was repeated for frequencies from 10 to 30 MHz in 10 MHz steps. Output levels were recorded.

(5) The procedure shown in subparagraphs B1-B4 was repeated using T-603 modem SN 881 and T-608 modem SN 888.

c. Test Data

(1) The frequency response of the system, using T-603 modem SN 884 and T-608 modem SN 887, is shown in table V and figure 3. The absolute output level at 1 MHz was 2.9 dBm.

(2) The frequency response of the system, using T-603 modem SN 881 and T-608 modem SN 888, is shown in table VI and figure 4. The absolute output level at 1 MHz was 2.9 dBm.

TABLE V. FREQUENCY RESPONSE OF 20 MHz ANALOG FIBER OPTIC SYSTEM USING T-603 MODEM SN 884 AND T-608 MODEM SN 887

FREQ (kHz)	GAIN (dB)	FREQ (MHz)	GAIN (dB)
1	2.9	1	2.9
2	2.9	2	2.9
3	2.9	3	2.9
4	2.9	4	2.8
5	2.9	5	2.8
6	2.9	6	2.8
7	2.9	7	2.9
8	2.9	8	2.9
9	2.9	9	2.9
10	2.9	10	2.9
20	2.9	20	2.5
30	2.9	30	1.0
40	2.9	40	-1.1
50	2.9	50	-4.1
60	2.9	60	-6.7
70	2.9	70	-9.0
80	2.9	80	-14.1
90	2.9	90	-23.7
100	2.9		

TABLE VI. FREQUENCY RESPONSE OF 20 MHz ANALOG FIBER OPTIC SYSTEM USING T-603 MODEM SN 881 AND T-603 MODEM SN 888

FREQ (kHz)	GAIN (dB)	FREQ (MHz)	GAIN (dB)
1	2.8	1	2.9
2	2.9	2	2.8
3	2.9	3	2.7
4	2.9	4	2.6
5	2.9	5	2.6
6	2.9	6	2.6
7	2.9	7	2.6
8	2.9	8	2.6
9	2.9	9	2.6
10	2.9	10	2.6
20	2.9	20	2.7
30	2.9	30	1.7
40	2.9	40	-0.8
50	2.9	50	-3.7
60	2.9	60	-7.0
70	2.9	70	-11.7
80	2.9	80	-20.5
90	2.9	90	-29.1
100	2.9		

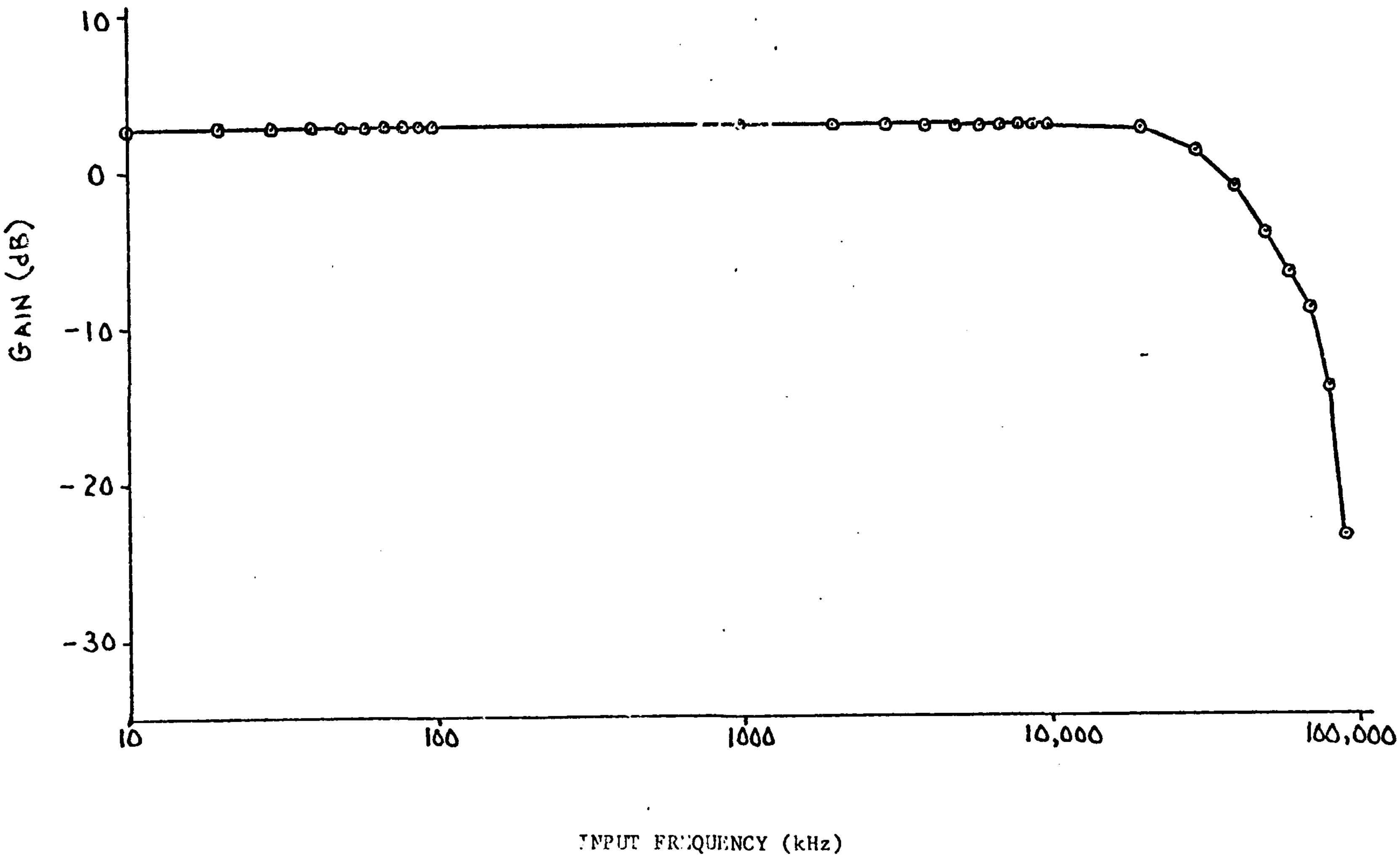


Figure 3. Frequency response of 20 MHz analog fiber optic system using T-603 modem SN 884 and T-608 modem SN 887.

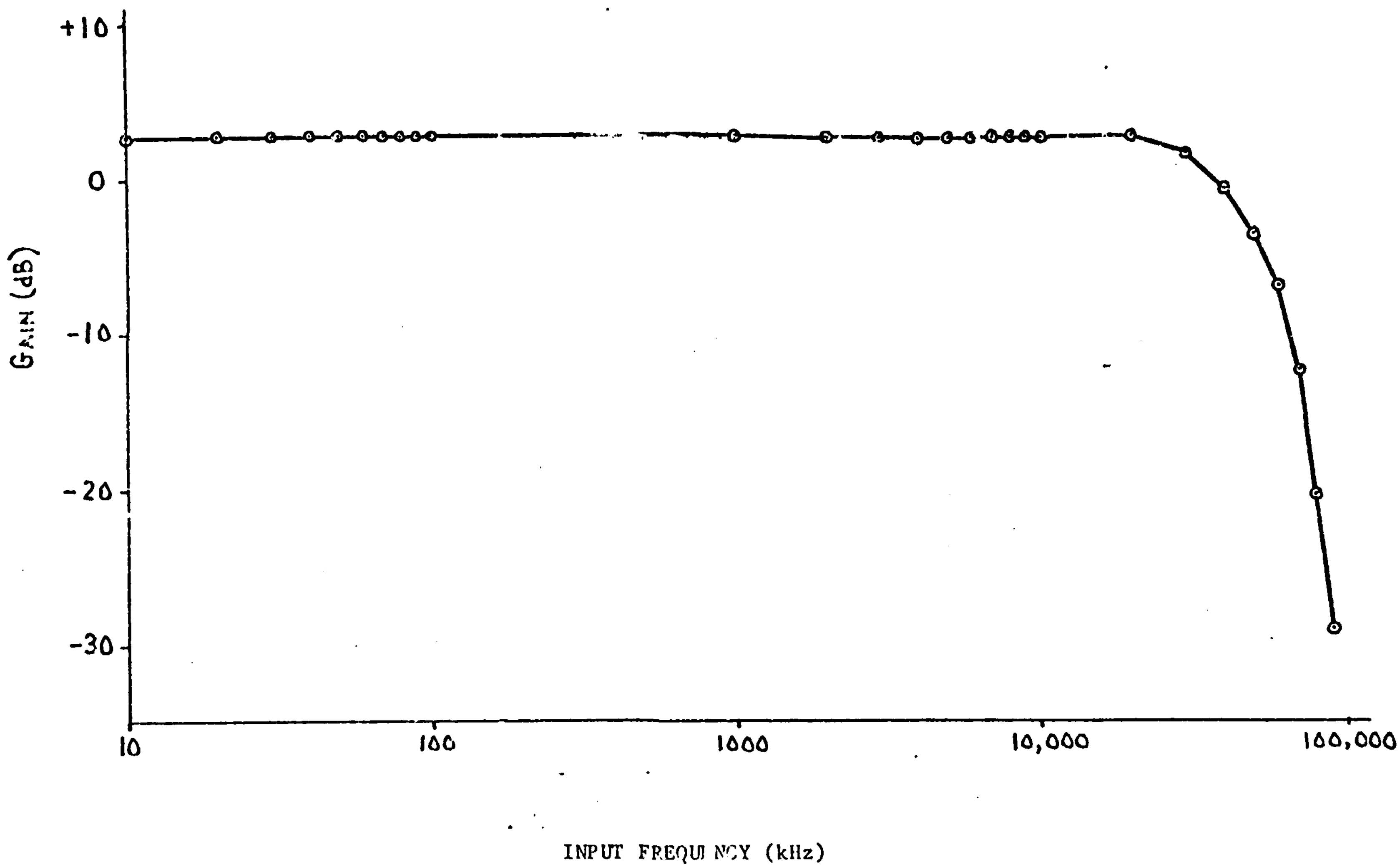


Figure 4. Frequency response of 20 MHz fiber optic system using T-603 modem SN 881 and T-608 modem SN 888.

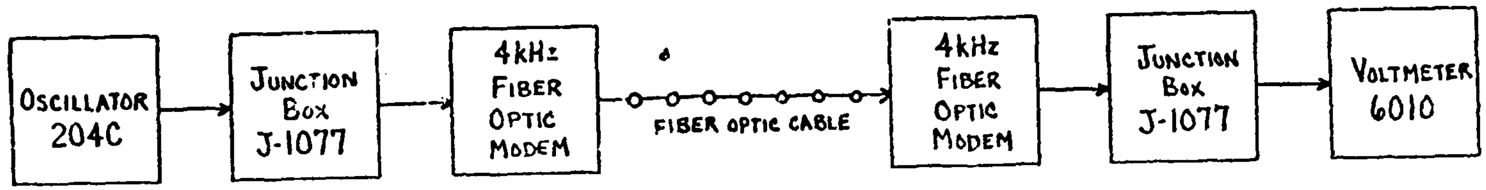


Figure 5. Test configuration for frequency response of 4 kHz fiber optic system.

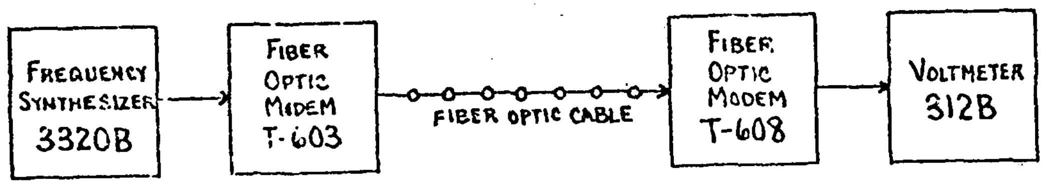


Figure 6. Test configuration for frequency response of 20 MHz fiber optic system (1 kHz - 1 MHz).

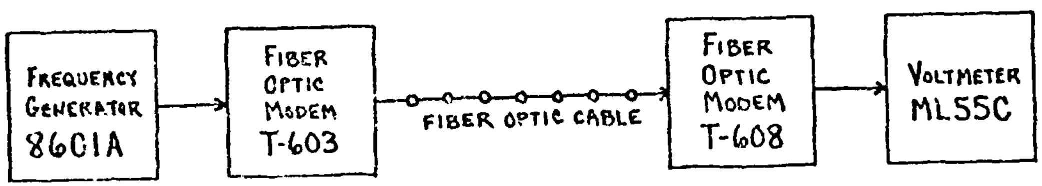


Figure 7. Test configuration for frequency response of 20 MHz fiber optic system (1 - 90 MHz).

3. BIT ERROR RATE - 1.544 Mb/s FIBER OPTIC SYSTEM

a. Equipment Used

(1) BAMI TTL Interface Converter, SN 2604, 2605

(2) BOMAR Error Rate Test Set 271B, SN 304

(3) HP Electronic Counter 5245L, SN 648-11495

(4) HP Preset Unit 5264, SN 616-00584

(5) HP Digital Printer 5103, SN 343

(6) Valtec Fiber Optic Modem TTIC-D1, SN 1056, 1099, 1153, and 1187

(7) Valtec Fiber Optic Cable (10 and 100 meter lengths)

b. Data Acquisition Procedure

(1) The test equipment was connected as shown in figure 8. Ten meter lengths of fiber optic cable were used to interconnect the modems.

(2) The error rate test set was set for individual error mode, automatic synchronization, and continuous count. It then input a data bit stream into the system at a T-1 rate (1.544 Mbs).

(3) Errors were counted by the electronic counter and recorded by the digital printer. The preset unit limited the time interval of each test run to 5 minutes; thus, 463.2 megabits of data were entered into the system on each run. This procedure was repeated for three, 5 minute test runs.

(4) The 10-meter lengths of fiber optic cable were replaced by 100-meter lengths. Then, the procedure shown in subparagraphs b.(2) - b.(3) was repeated.

c. Test Data

(1) No bit errors were recorded for any run with either 10- or 100-meter lengths of fiber optic cable.

(2) Since no errors were observed in 463.2 megabits of data, it can be stated that the point estimate system bit error rate for a T-1 input is bracketed by the interval:

$$0 \leq \text{point estimate bit error rate} \leq 2.2\ 10^{-9}\ \text{errors/bit}$$

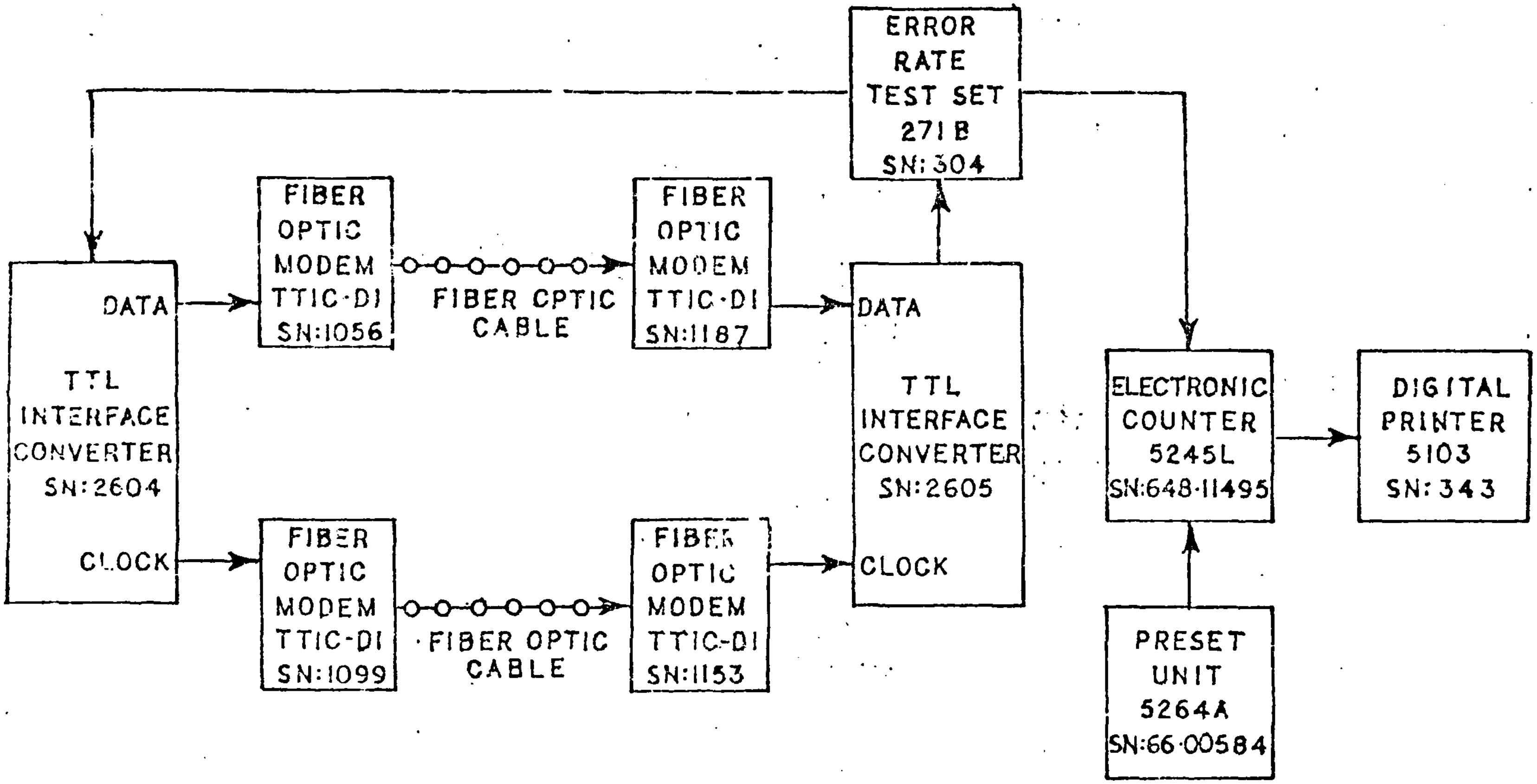


Figure 8. Test configuration for bit error rate of 1.544 Mbs fiber optic system.

AD-A103 525   ARMY COMMUNICATIONS-ELECTRONICS ENGINEERING INSTALLAT--ETC F/G 17/2.1
ZERO LENGTH INTRASTATION FIBER OPTICS LINKS TEST AND EVALUATION--ETC(U)
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4. BIT ERROR RATE - 20 MHz ANALOG FIBER OPTIC SYSTEM

a. Equipment Used

(1) BOMAR Error Rate Test Set 271B, SN 304

(2) HP Electronic Counter 5245L, SN 648-11495

(3) HP Preset Unit 5264, SN 616-00584

(4) HP Digital Printer, SN 343

(5) AN/FRC-162 M/W Radio, SN 31A

(6) AN/FCC-97 Digital Multiplexer, SN 01J0033

(7) Waveline 20 dB RF Attenuator 506-20, SN 613, 615

(8) Waveline 40 dB RF Attenuator 506-40, SN 579, NSN

(9) Terracom M/W Radio, NSN

(10) ITT Fiber Optic Modem T-608, SN 887, 888

(11) ITT Fiber Optic Modem T-603, SN 881, 884

(12) ITT Fiber Optic Cable, 10 and 100 meter lengths

b. Data Acquisition Procedure

(1) The test equipment was connected as shown in figure 9. Ten meter lengths of fiber optic cable were used to interconnect the modems.

(2) The transmitter of the Terracom M/W radio was connected through a 20-dB and a 40-dB attenuator to the "in-house link" of the receiver of the AN/FRC-162 M/W radio. The transmitter of the AN/FRC-162 was connected through a 20-dB and a-40 dB attenuator to the receiver of the Terracom M/W radio. An input of 1 watt (30 dBm) from the Terracom radio into M/W radio into this loop-back arrangement produced a nominal receive signal level (RSL) of -30 dBm at the input to the receiver of both radios.

(3) The error rate test set was set for individual error mode, automatic synchronization, and continuous count. It then input a data bit stream into channel 4 of the AN/FCC-97 digital multiplexer at a T-1 rate (1.544 Mb/s).

(4) Errors were counted by the electronic counter and recorded by the digital printer. The preset unit limited the time interval of each test run to 5 minutes. This procedure was repeated for three, 5 minute test runs.

(5) The 10-meter lengths of cable were replaced by 100-meter lengths. Then, the procedure shown in subparagraphs b.(2) - b.(4) was repeated.

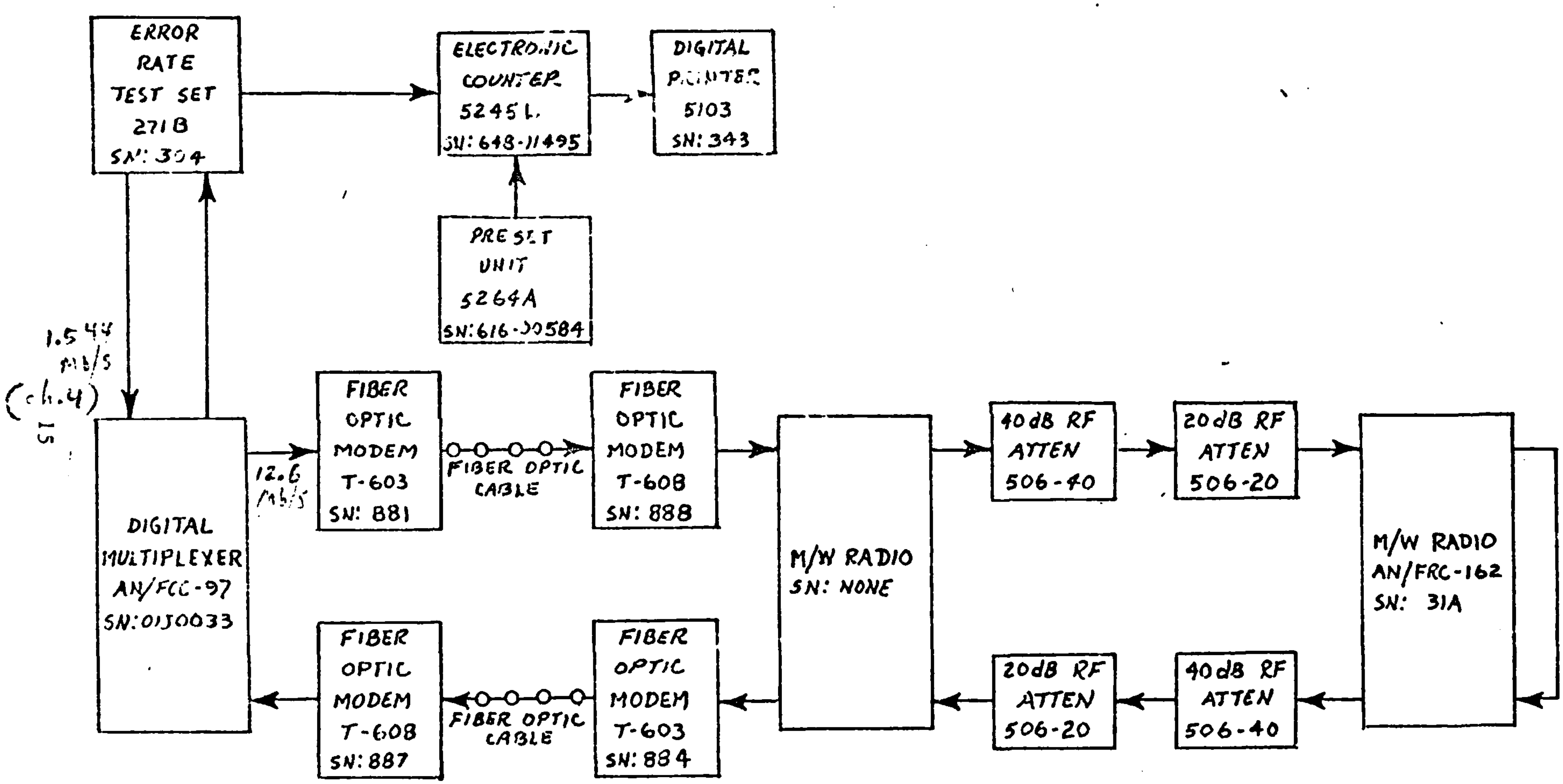


Figure 9. Test configuration for bit error rate of 20 MHz analog fiber optic system.

c. Test Data

(1) No bit errors were recorded for any run with either 10-meter or 100-meter lengths of fiber optic cable.

(2) Since no errors were observed in 463.2 megabits of data, it can be stated that the point estimate system bit error rate for a T-1 input is bracketed by the interval:

$0 \leq$ point estimate bit error rate $\leq 2.2\ 10^{-9}$ errors/bit

5. BIT ERROR RATE - COAXIAL CABLE SYSTEM WITH T-1 INPUT DATA RATE

a. Equipment Used

(1) Bomar Error Rate Test Set 271B, SN 304

(2) HP Electronic Counter 524L, SN 648-11495

(3) HP Preset Unit 5264A, SN 616-00584

(4) HP Digital Printer, SN 343

(5) AN/FRC-162 M/W Radio, SN 31A

(6) AN/FCC-97 Digital Multiplexer, SN 01J0033

(7) Waveline 20-dB RF Attenuator 506-20, SN 613, 615

(8) Waveline 40-dB RF Attenuator 506-40, SN 579, NSN

(9) Coaxial Cable RG-59, 10-meter and 100-meter lenghts.

(10) Terracom M/W Radio, NSN

b. Data Acquisition Procedure

(1) The test equipment was connected as shown in figure 10. Ten meter lengths of coaxial cable were used to interconnect the AN/FCC-97 multiplexer and the Terracom M/W Radio.

(2) The procedures shown in paragraphs 4.b.(2) - 4.b.(5) were used.

c. Test Data

(1) When 10-meter lengths of coaxial cable were used, no bit errors were recorded on any test run. Since no errors were observed in 463.2 megabits of data, it can be stated that the point estimate system bit error rate for a T-1 input is bracketed by the interval:

$0 \leq$ point estimate bit error rate $\leq 2.2\ 10^{-9}$ errors/bit

(2) When 100-meter lengths of coaxial cable were used, bit errors were recorded during each of the three runs as follows: Run #1, 2815 errors; run #2, 2729 errors; and run #3, 2771 errors. The respective point estimate bit error rates were 6.08×10^{-5}, 5.89×10^{-5}, and 5.98×10^{-5} errors/bit.

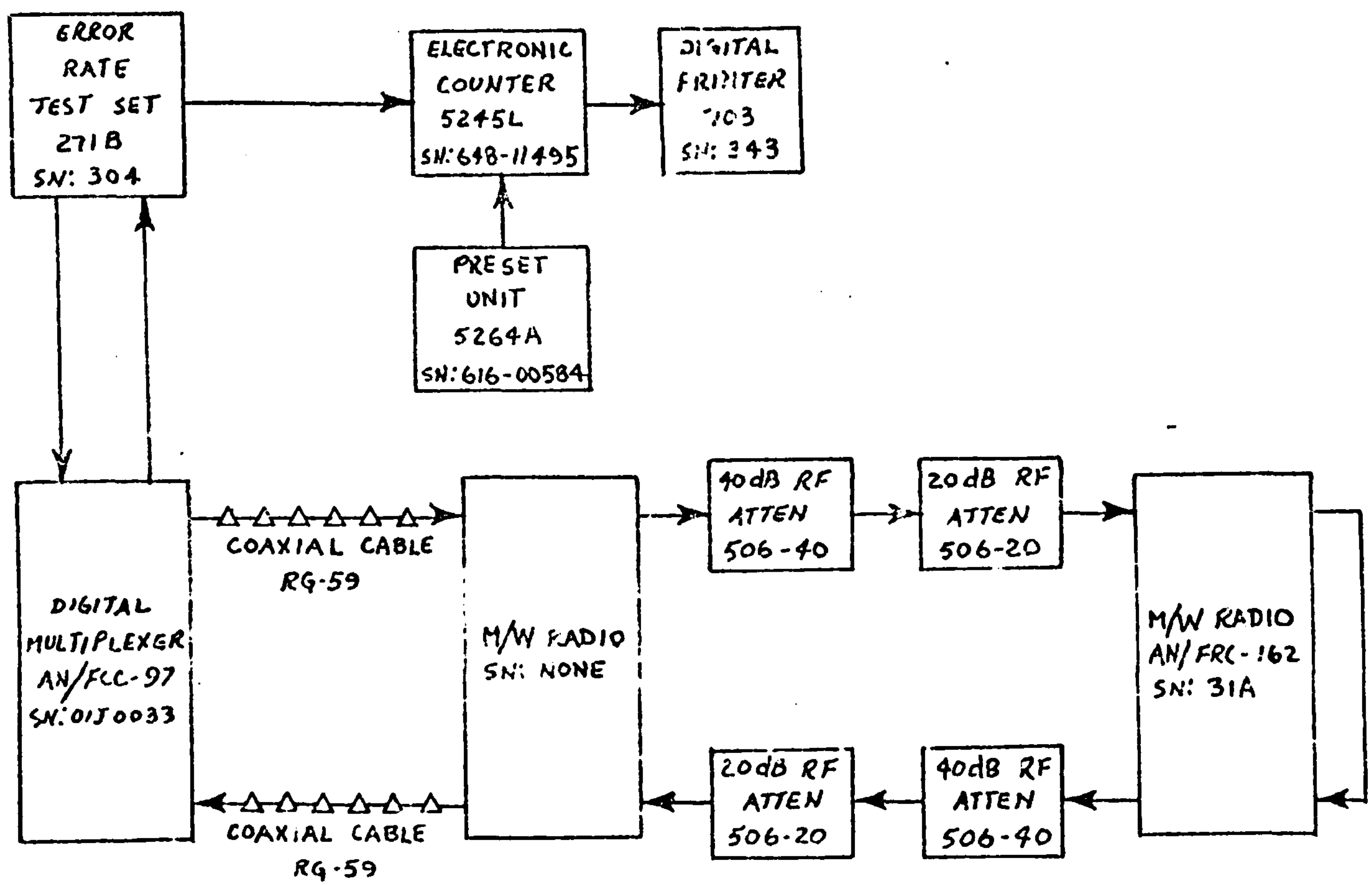


Figure 10. Test configuration of bit error rate for coaxial cable system.

(3) According to Technical Manual VICOM PSB-6020, section 3, page 1, paragraph 5, no more than 150 feet (45.72 meters) of coaxial cable should be used in this system configuration.

6. IDLE CHANNEL NOISE (ICN) - 4 kHz VOICE LINK WITH 26-PAIR METALLIC CABLE

a. Equipment Used

(1) As shown in reference 1a, inclosure 1, paragraph 1.1.A.2.

(2) NEC Noise Measuring Test Set 37BAQ, SN 8024.

b. Data Acquisition Procedure

(1) As shown in reference 1a, enclosure 1, paragraph 1.1.B.2.

(2) The HP-4940A TIMS was then replaced by the NEC 37BAQ. The procedure in subparagraph b.(1) was repeated.

c. Test Data

(1) The HP-4940A TIMS recorded an ICN level of 0 dBrnc for each pair of the 26-pair cable. Although the measurement range of the HP-4940 TIMS is from 0 to 90 dBrnc, the equipment publication states that readings below 10 dBrnc may exceed the sensitivity of the instrument and, therefore, should be interpreted as "less than 10 dBrnc".

(2) The NEC 37BAQ recorded an ICN level of -5 dBrnc for every pair, thus, the ICN for each pair of the 26-pair metallic is less than or equal to -5dBrnc.

7. CROSSTALK - 4 kHz VOICE LINK WITH 26-PAIR METALLIC CABLE

a. Equipment Used

(1) As shown in reference 1a, inclosure 1, paragraph 1.2 A.2.

(2) NEC Noise Measuring Test Set 37 BAQ, SN 8024.

b. Data Acquisition Procedure

(1) As shown in reference 1a, inclosure 1, paragraph 1.2.B.2.

(2) The HP-4940A TIMS was then replaced by the NEC 37BAQ. The procedure in subparagraph B1 was repeated.

c. Test Data

(1) The HP-4940A TIMS recorded a crosstalk level of 0 dBrnc for each pair of the 26-pair cable, with the exception of pair #15. As stated in paragraph 6C1, these readings should be interpreted to mean an ICN level less than 10 dBrnc.

(2) ICN levels for pair #15 were recorded as 0 dBrnc when a -10 dBm tone at 1004 Hz was injected on pair #1 or #2, 5 to 6 dBrnc when tone was injected on pairs #3 through #7, and 10 to 13 dBrnc when tone was injected on pairs #8 through #14 or #15 through #26. This cable pair was considered to be defective.

(3) The NEC 37BAQ recorded a crosstalk level of -5 dBrnc for every pair except pair #15, which was known to be defective.

8. INSTALLATION/RECOVERY TIMES

a. Installation and recovery times for the 1.544 Mb/s fiber optic system and its metallic (coaxial) counterpart are shown in reference 1a, inclosure 1, paragraph 2.7. Times for the fiber optic system were normally greater; this time differential was the result of the additional time necessary to connect (or disconnect) input/output devices to the fiber optic modems and initialize (or deintialize) the modems.

b. More detailed data could be obtained in a study conducted by human factors engineers. However, the additional precision to be gained from a detiled survey of this nature was not considered to be cost effective (see reference 1b, paragraph 2i).

9. CONDITION DIPHASE PATTERN TEST EQUIPMENT SETTINGS

a. During the initial test of the bit error rate of the 1.544 Mb/s fiber optic link, a condition diphase pattern (CDP) generator and error correlator were used to inject data bits into the link at 16 or 32 kbs and record resulting bit errors. The test procedure shown in reference 1a, paragraph 2.4.B, should have included the switch settings for this equipment, which were: Data rate - 16 or 32 kbs, operational mode - errors, and clock-internal.

b. Note that additional testing of the bit error rate of this link was conducted for a T-1 (1.544 Mb/s) data rate. See paragraph 3 of this report.

10. IDLE CHANNEL NOISE (ICN) - COAXIAL CABLE WITH T-1 INPUT DATA RATE

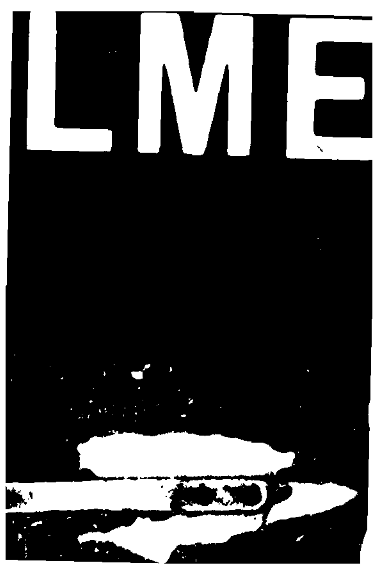
a. Results of initial testing for ICN induced by the presence of 10 meters of coaxial cable in a T-1 system are shown in reference 1a, table V. On channel #7, the cable induced 4 dB additional ICN into the system. The magnitude of this figure was questioned in reference 1b, paragraph 2f.

b. Additional testing was conducted in accordance with reference 1a, paragraph 2.1.B.3 Channel cards from the TSEC/CY-104 were interchanged and test equipment settings verified. The cable continued to induce 4 dB of additional ICN into the system.

11. CYCLIC FLEX 1.544 MBs AND 20 MHz FIBER OPTIC SYSTEMS

a. Fiber optic cables used in the 1.544 MBs and 20 MHz fiber optic systems were repeatedly flexed to determine whether possible cable degradation would result in a decrease in the system's optical power output. Results are shown in reference 1a, tables XII and XXIII. Optical power output is shown in microwatts (uW).

b. The optical power meter used in this test (see reference 1a, paragraph 2.6.A.4) had not been calibrated. It was compared to a calibrated AG&G, Electro-Optic Division Radiometer/Photometer, Model 550-1, SN 3274. When the optical power meter read 17 microwatts, the calibrated radiometer/photometer read 14 microwatts (using the test procedure shown in reference 1.a, paragraph 2.6.B).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