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JOHN F. KENNEDY SPACE CENTER
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EVALUATION AND ANALYSIS OF THE ANSI X3T9.5 (FDDI) PMD AND PROPOSED SMF-PMD AS INFLUENCED BY VARIOUS FIBER LINK CHARACTERISTICS

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Abstract

The purpose of this project is to evaluate the parameters of operations outlined in the ANSI X3T9.5 (FDDI) Physical Medium Dependent (PMD) and Single Mode Fiber PMD standards based on conditions present in the KSC fiber optic cable plant. From the KSC fiber profile, it would be necessary to develop the modifications needed in existing FDDI PMD and proposed SMF-PMD standards to provide for FDDI implementation and operation at KSC. This analysis should examine the major factors that influence the operating conditions of the KSC fiber plant. These factors would include, but are not limited to the number and type of connectors, attenuation and dispersion characteristics of the fiber, non-standard fiber sizes, modal bandwidth, and many other relevant or significant fiber plant characteristics that effect FDDI characteristics. This analysis needed to gain a better understanding of overall impact that each of these factors have on FDDI performance at KSC.

Summary

This report evaluates the parameters of operations outlined in the ANSI X3T9.5 FDDI PMD standards and provides results based on the conditions present in the KSC Fiber Optic Cable Plant. This involves the development of an average link profile for KSC including limits for the multimode fiber links in the LC39 and industrial area as well as between them. The profile of the KSC Fiber is examined through the major factors that influence the operating conditions of the KSC Fiber Plant. These factors include the number and the type of connectors, non-standard fiber sizes, modal bandwidth and all other significant fiber plant characteristics that effect FDDI performance. The performance results for the Fiber Optic Plant at KSC are summarized and future research suggestions are given. Finally, the recommendation for the hardware purchases relevant to FDDI bandwidth performance testing is stated.

List of Acronyms

KSC- Kennedy Space Center

ANSI- American National Standards Institute

FDDI- Fiber Distributive Data Interface

PMD- Physical Medium Dependent

MMF- Multi Mode Fiber

SMF- Single Mode Fiber

LAN- Local Area Networks

OSIRM- Open System Interconnection Reference Model

MAC- Medium Access Protocol

BER- Bit Error Rate

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I. Introduction

I. 1. FDDI Background

1980's lack of standards hampered the growth of the short-to medium- distance fiber optic market, including LAN's and private point-to-point premise communication. In Oct. 1982 ANSI committee X3T9.5 was chartered to develop a high speed data networking standard that specified a packet switching LAN backbone that transported data at highthroughput rates over a variety of fiber. The FDDI grew out of the need for high speed interconnections among a mainframes, minicomputer and associated peripherals. The FDDI specifications encompass a token passing network enveloping two pairs of fibers operating at 100 Mb/s. The 1991-1992 standard covers the first two layers of OSIRM, through the MAC Sublayer. The optical based FDDI-LAN was design to enjoy the same type of serial interconnection provided by LAN's while providing a high bandwidth, inherent noise immunity and security offered by fiber. The FDDI is meant to provide inexpensive connectivity, thus, it focuses on the 100 Mb/s rates. The FDDI accommodates asynchronous and,in the future synchronous data transmission and is designed as a fiber optic network. This involve standardization in the following areas.

1. Duplex Optical Connectors
2. Fiber Characteristics
3. Optical bandwidth
4. Bypass relays
5. Cable assemblies

The FDDI ring is designed on overall BER < 10 to -9. The Network can tolerate up to 11dBm between the stations, and can support a total cable distance of 100 Km around the ring with 500 attachments (1000 physical connections for a total fiber path of 200 km). The intrinsic topology of FDDI is a counter-rotating token-passing ring . At least part of the reason why FDDI employs a ring topology is based on the characteristics of the optical communication. Bus and passive star topologies would require the optical transmission to be detected at several sources simultaneously. Although, practical fiber optical taps are beginning to become available, the attenuation is still such that number of nodes is relatively limited. Because the fiber optical transmission is best handled with a point-to-point configuration this aspect is included in FDDI's definition.

I. 2. FDDI requirements-optical test performance-Multimode Fibers I. 2.1. Attenuation

Required attenuation less than 1dB/km at 1300 nm transmission measuring standard subject to EIA standard RS-455; FOTP-46 or FOTP-53.

Attenuation uniformity no greater than O.2dB at 1300 nm using OTDR per EIA standard RS-455, FOTP-59.

I. 2.2. Multimode bandwidth:

At- 3dB optical bandwidth for each optical fiber in the cable y=1,.B-L product > 1GHz-km at 1300 nm +- 50 nm

EIA standard RS-455,FOTP-30 (frequency domain)

EIA standard RS-455,FOTP-51 (time domain)

I. 2.3. Numerical aperture, N.A:

N.A. equal to 0.2 +- 0.02 at 1300 nm optical spectrum window

EIA standard RS-455, FOTP-47 at 1300 nm.

I. 2.4. Multimode Chromatic Dispersion

Zero-dispersion wavelength point at 1300 +- 13 nm range with zero-dispersion slope no greater than 0.101 ps/nm2.km

EIA standard RS-455,FOTP-167 test method.

I. 3. KSC Fiber Optics Cable Plant.

At the present, KSC lab has as shown in Fig. 1, a number of optical communication lines installed for a single mode and multi-mode transmission. The MMF utilizes the 1300 nm carrier wavelength with a theoretical fiber bandwidth in excess of 1000 GHz.

The current FDDI requirement of 125 Mbs at the 1300 nm window utilizes only a small percentage of this.

Fig. 2 (Thanks to Dr. H. Bates) shows the actual testing diagram for the fiber loop between EDL facility and Banana River Repeater Station of a total distance of 12.4 Km.

This configuration has 12 independent fiber links and utilizes the biconic connectors for fiber jumpers and testing equipment.

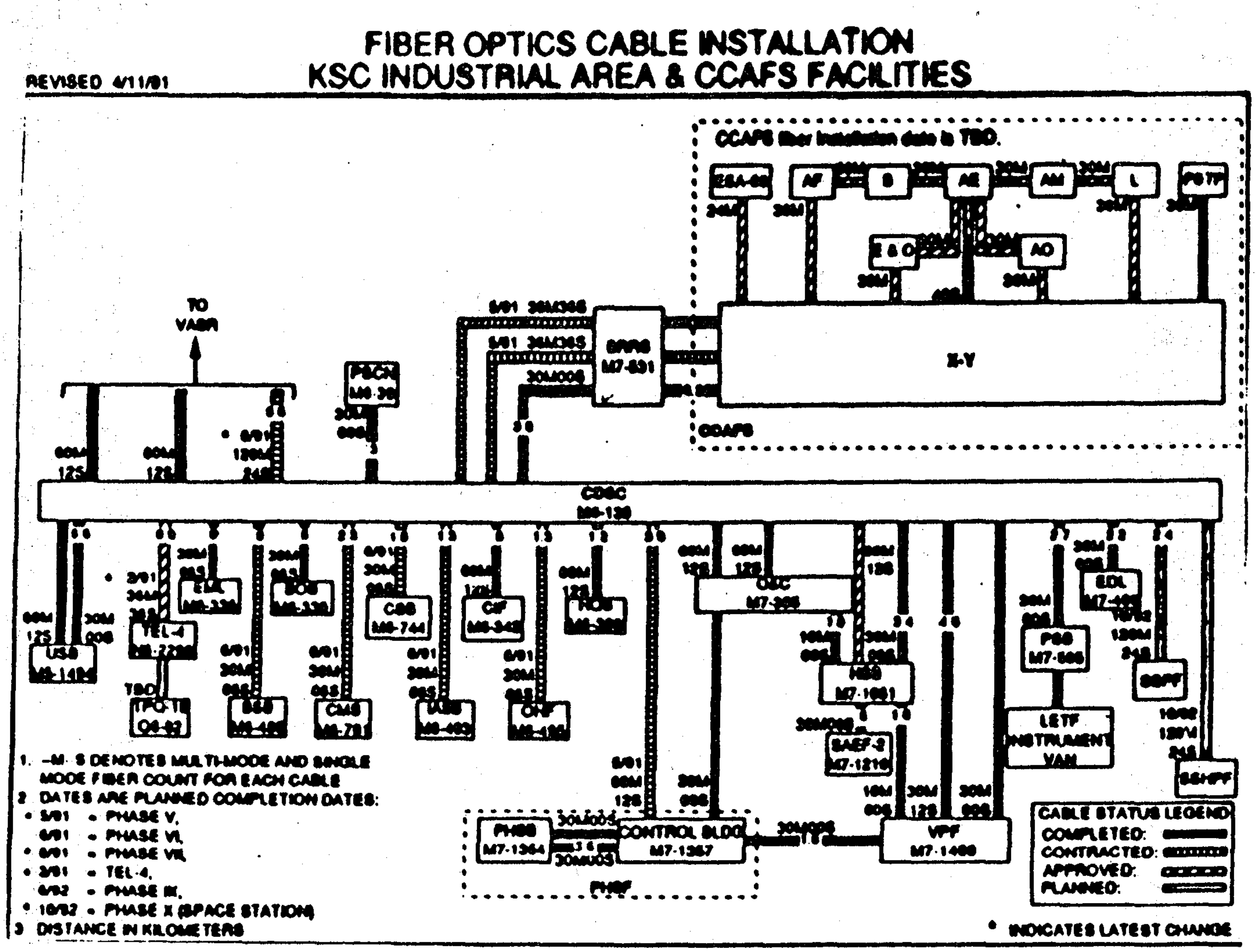


Fig.1 Fiber Optics Cable Installation at KSC

This configuration has 12 independent fiber links and utilizes the biconic connectors for fiber jumper and testing equipment.

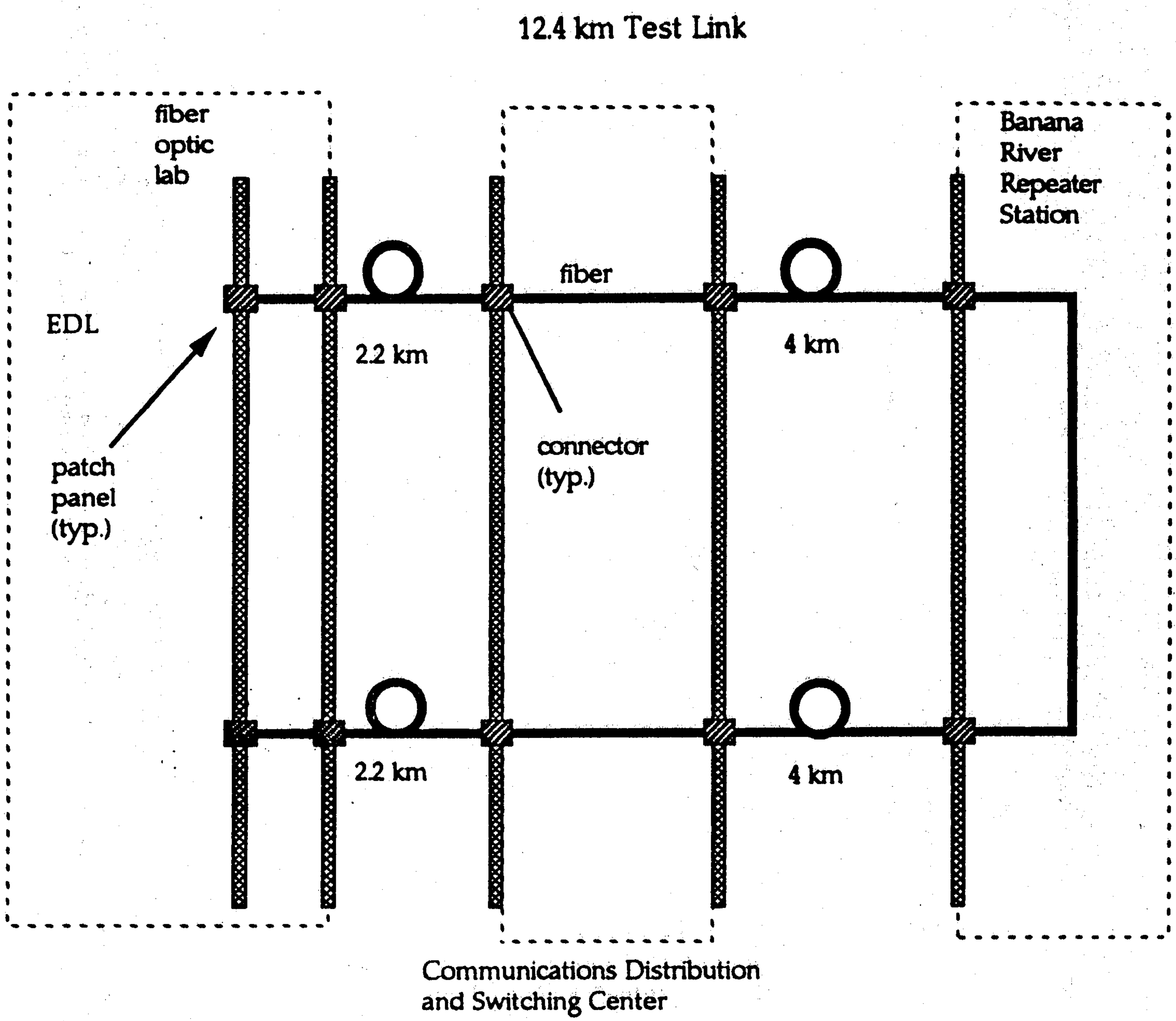


Fig. 2 The 12.4 Km Test Link

II. Laboratory test equipment

2.1. Optical Time Domain Reflectometer (OTDR)

In order to test the multimode fiber Bandwidth subject to the relevant EIA standard the TD - 9960 Local Area Network Optical Time Domain Reflectometer was used. The 9960 system consist of the main frame and large variety of plug-in optical modules, plus a fully buffered four inches digital X-Y plotter. This instrument incorporates a number of technical advances such as N-point averaging for rapid data acquisition, log transformations performed in software eliminating the linearity and temperature problem associating with analog techniques, etc. Splice loss measurements are extrapolated using curve fitting techniques for greater accuracy. Help facility is also incorporated into the instrument via the CRT display to provide instant access to information on every aspect on the use of the TD-9960(Appendix A for spects).

2.2. Optical Spectrum Analyzer

An ANRITSU optical spectrum analyzer model : MS 9001 B/BI was used to perform spectral analysis of the coherent sources used in testing the fiber. The optical spectrum analyzer is a high-speed accurate instrument design to measure the luminous spectra of Laser diodes or LED's in the range of 0.6 to 1.75 nm. Its features include wide-dynamic range and excellent linearity,high-speed measurements, high sensitivity, guaranteed level accuracy, auto-ranging function half-bandwidth autoreading function , etc.

2.3. Lightwave Component Analyzer

The Fiber optic channels were tested using the Hewlett Packard light-wave component Analyzers HP 8702 and HP 83410 B with optical accessories: light wave source; HP 8301 A, and lightwave receiver; HP 83410 B and RF 11889 A interface kit.(provided by H.P. Company). The HP 8702 analyzer is a measuring system that injects a modulated signal into a test device and compares this modulated input signal to the signal which is transmitted or reflected by the test device. This comparison of the reflected or transmitted signal to the incident signal results in a ratio measurement that characterizes the test devices' response. A light wave component analyzer, similar to a network analyzer, provides an electrical signal to modulate a light-wave source. It also provides an electrical receiver section that compares the transmitted and reflected (demodulated) electrical signal to the RF modulation signal. The HP 8702 also provides new calibration routines and measurement features for characterizing opto-electrical and electro-optical devices directly and conveniently.

III. Characterization of KSC Fiber Links

3.1 Typical Fiber Test Link.

The Fiber optics laboratory in the EDL building has a series of a multi-mode and single-mode fiber optic links as shown in Fig. 3-1

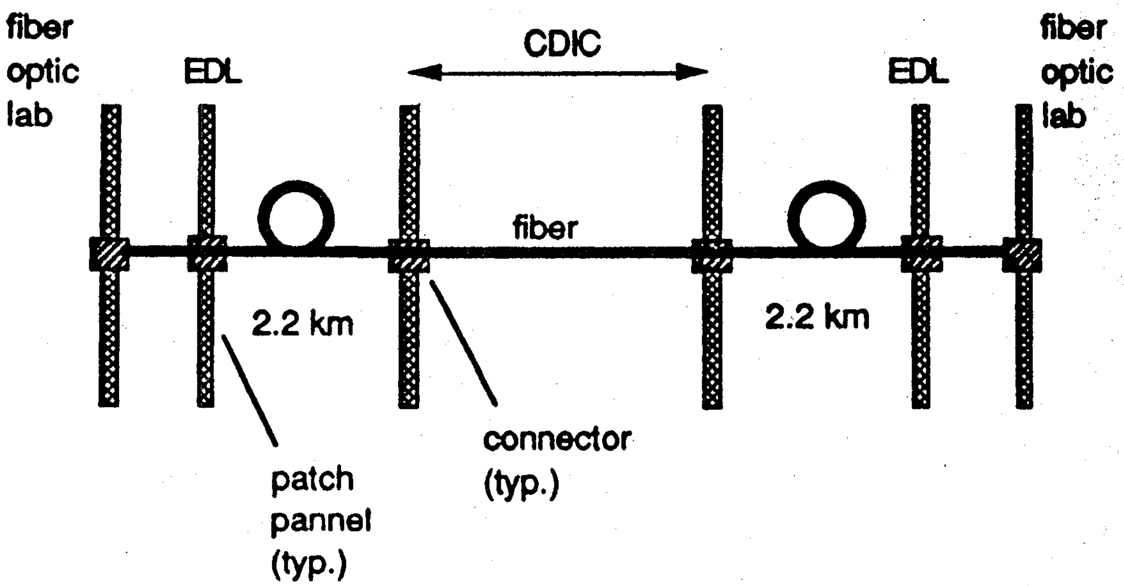


Fig 3.1 Fiber Optic Link at KSC

3.2. Attenuation Loss vs Fiber Links Length.

The attenuation loss of these links was measured as a function of the distance and number of connectors using the TD-9960 OTDR. Typical response shown in Fig. 3.2 for the link 1-2, indicates the attenuation loss in dB vs distance, loss on a biconic connectors and some reflective faults. (channels 3-12 in appendix B).

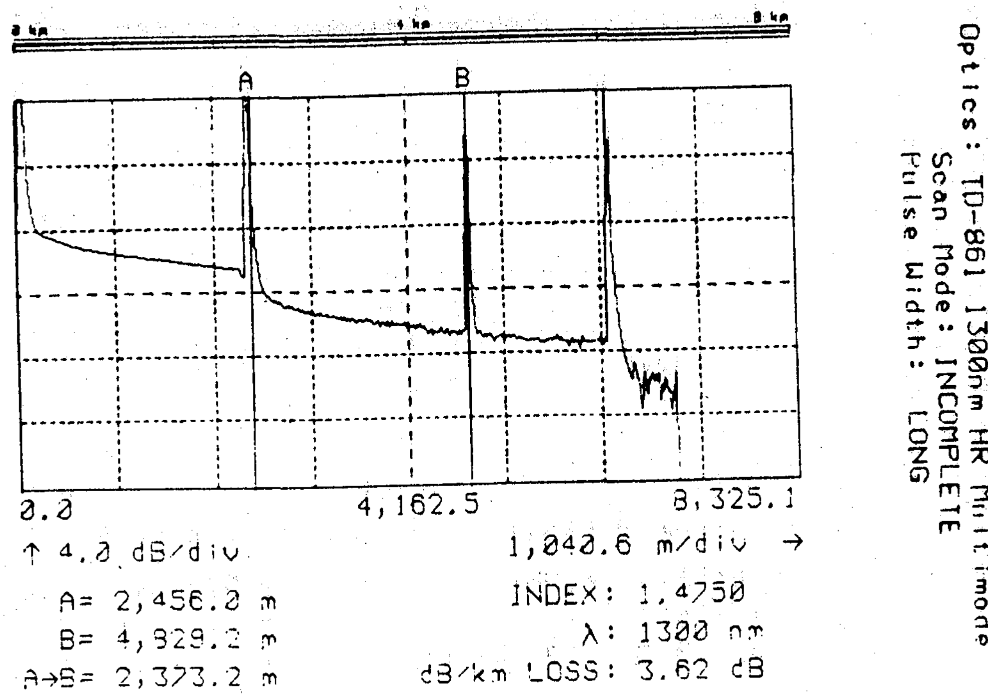


Fig. 3.2 Attenuation vs Length for MMF Link 1-2

Fig. 3.3 shows the attenuation for the link 2-1 (channels 3-12 in appendix B)

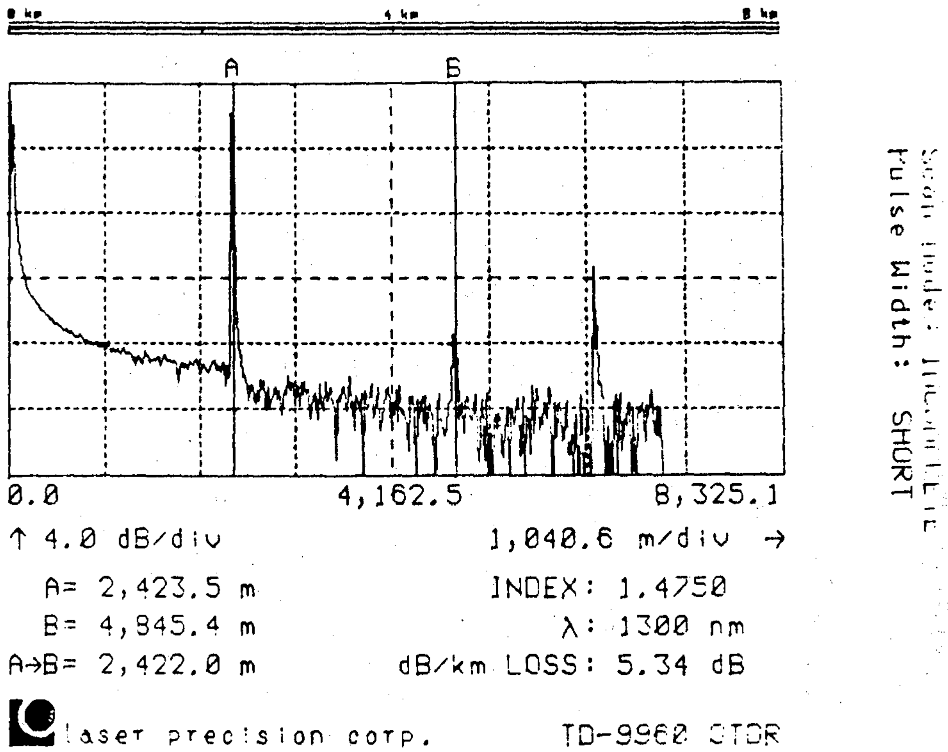


Fig 3.3 Attenuation for MMF Link 2-1

Fig. 3.4 shows the effect of an extra 1,410 m link with two additional biconic connectors. The reflective faults are shown to be a direct results of the biconic connectors.

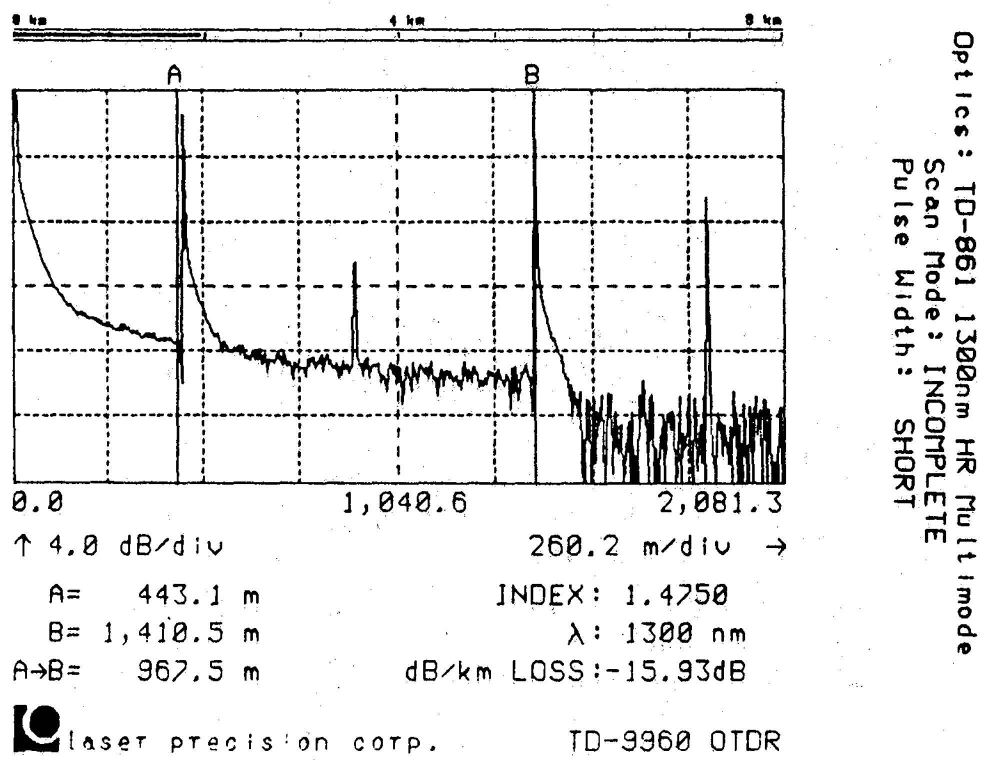


Fig. 3.4 Attenuation for 1410m MMF Link

Fig. 3.5 shows the spectral characteristics of the OTDR laser source at 1300 nm range for the future references.

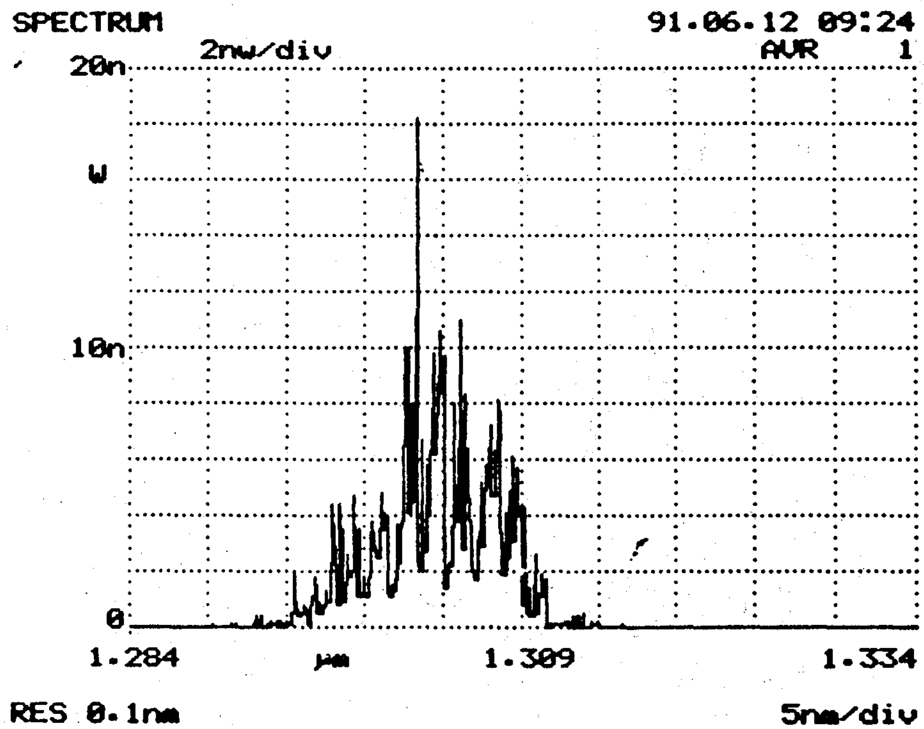


Fig. 3.5 Spectral Characteristic for OTDR Laser Source

3.3 Bandwidth Performance For KSC Fiber Link.

The lightwave component analyzer HP 8702 was used to measure the bandwidth performance of the KSC Fiber Link. The standard laser source HP 83401 A was used as a light source. The spectral characteristic of HP 83401 A is shown in Fig. 3.6

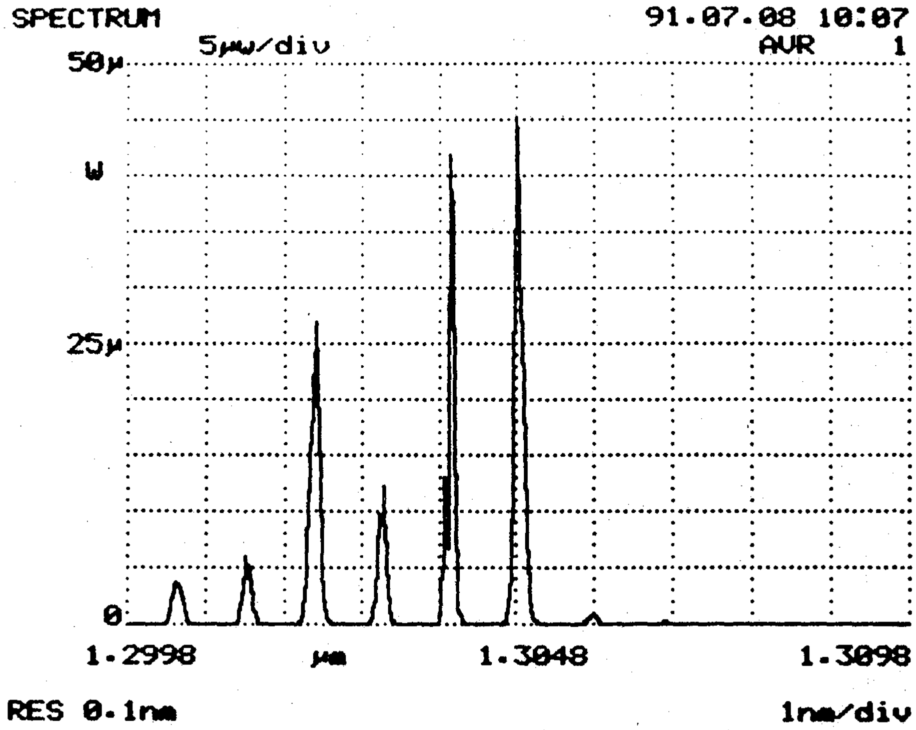


Fig. 3.6. HP 83401A Laser Source Spectral characteristic.

The warmup process and instability of HP Laser source as a function of time is shown in appendix C.

The bandwidth response for the KSC fiber Link 1-2 is shown in fig. 3.7. The -3dB bandwidth indicated by marker 1 suggest the 443.5 MHz optical bandwidth

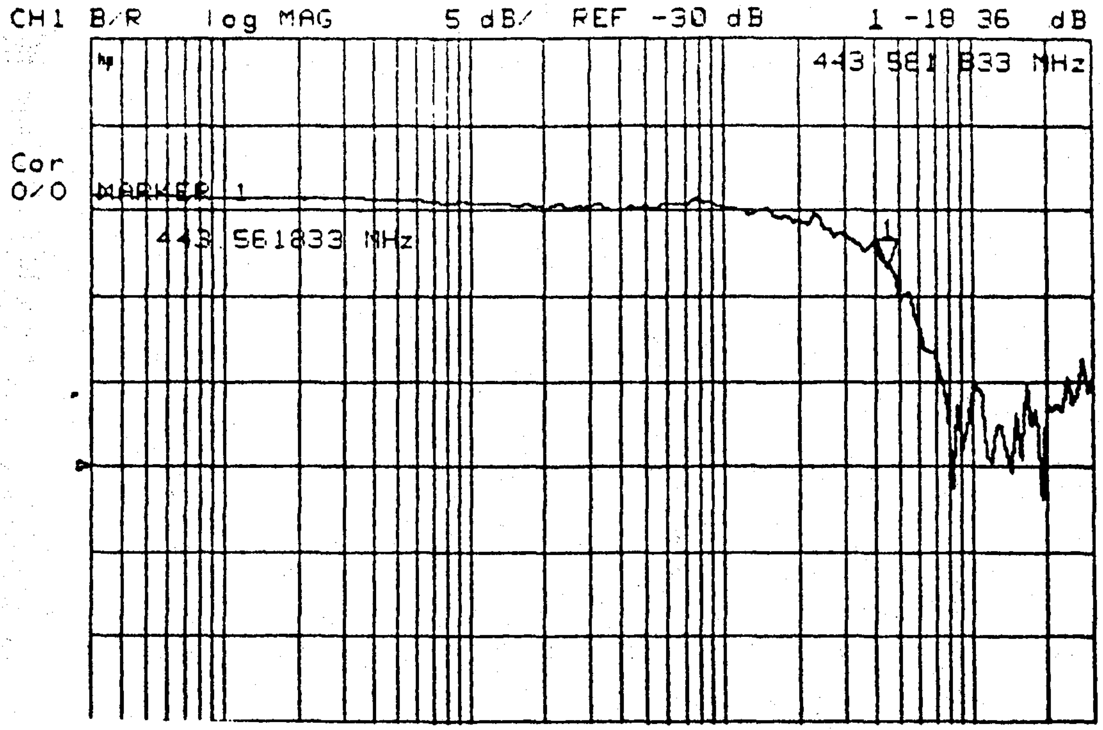


Fig.3-7 Gain vs. Frequency for the KSC link 1-2

The bandwidth response for the link 3-12 is shown in appendix D.

Fig 3.8 shown the bandwidth degradation with increased fiber link length and the -3dB cutoff at 343.8 MHz.

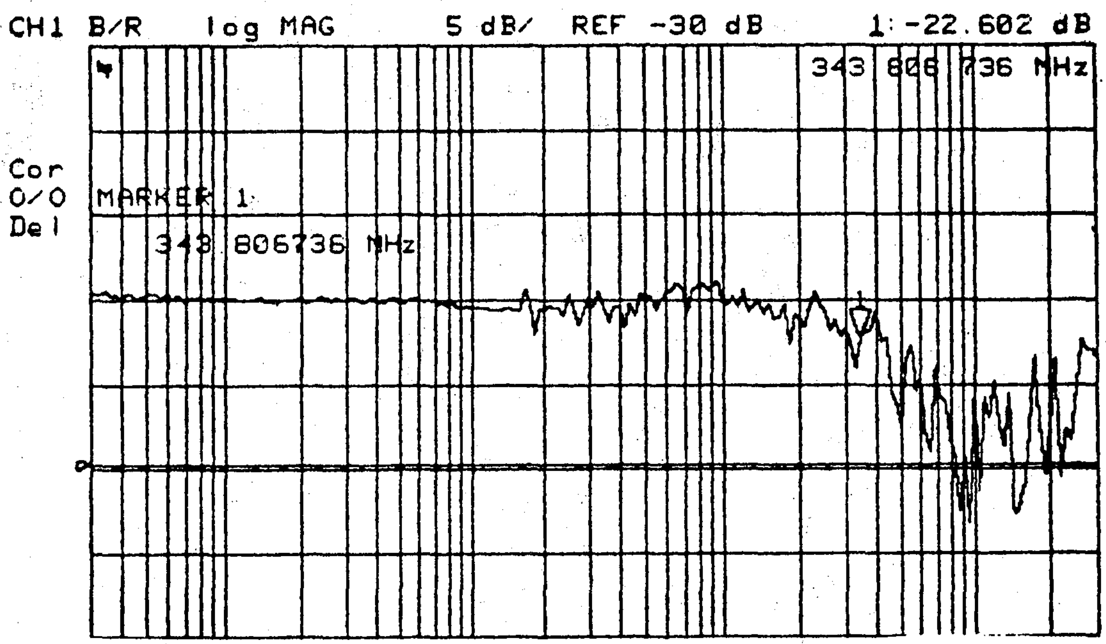


Fig 3.8 Bandwidth degradation for link 1-2 with additional 1.4km MMF length.

The effect of an extra biconic connectors is examined in Fig. 3.9. The 7 additional connectors were placed between the Laser source and the link 1-2. showing no noticeable degradation in the bandwidth .

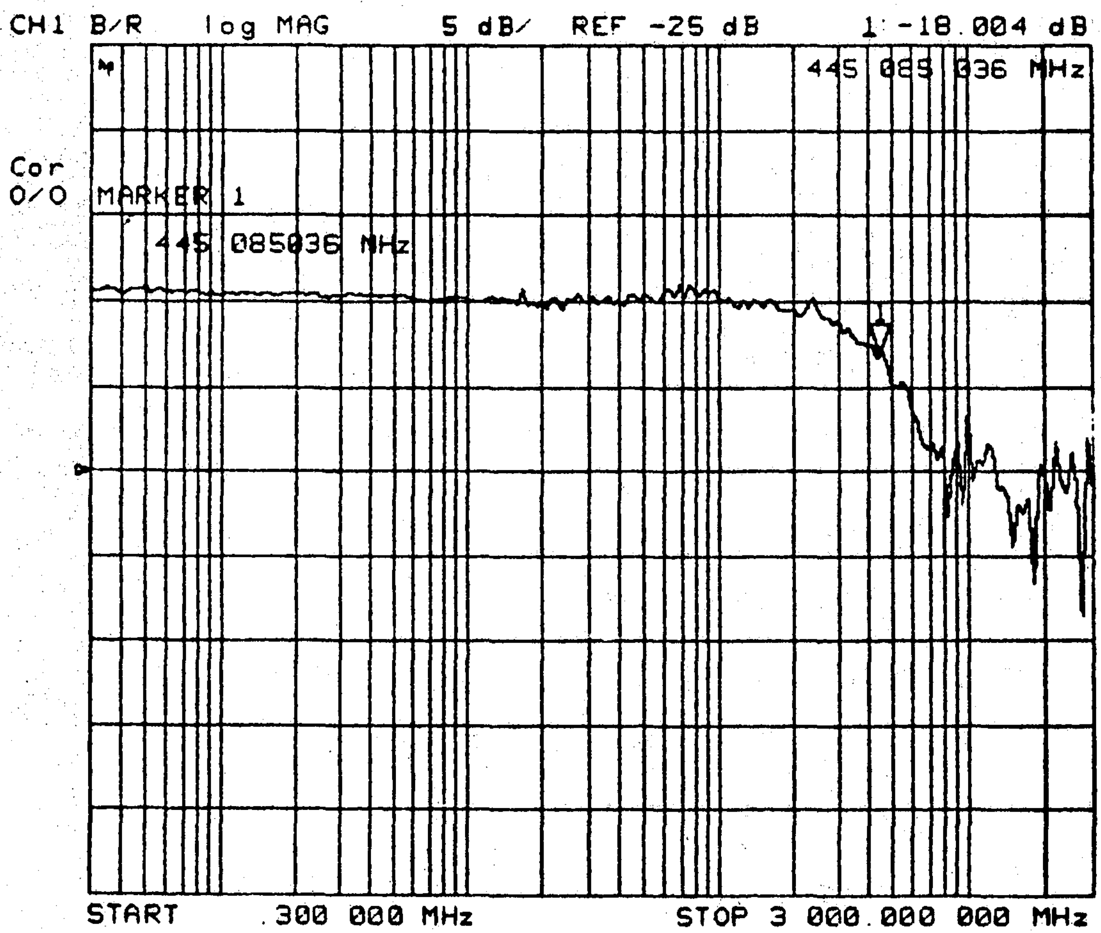


Fig. 3.9 Bandwidth response vs. additional biconic connectors

Fig.3.10 shows the bandwidth performance for the link 1-2 with additional 7 biconic connectors placed between link an optical detector. As in Fig. 3.9. there was no visible degradation in system performance. In appendix E, the effect of additional biconic connectors placed at the detector end for links 3-12 is shown. As previously observed, there was no degradation in the system performance (bandwidth) as a result of these additional biconic connectors.

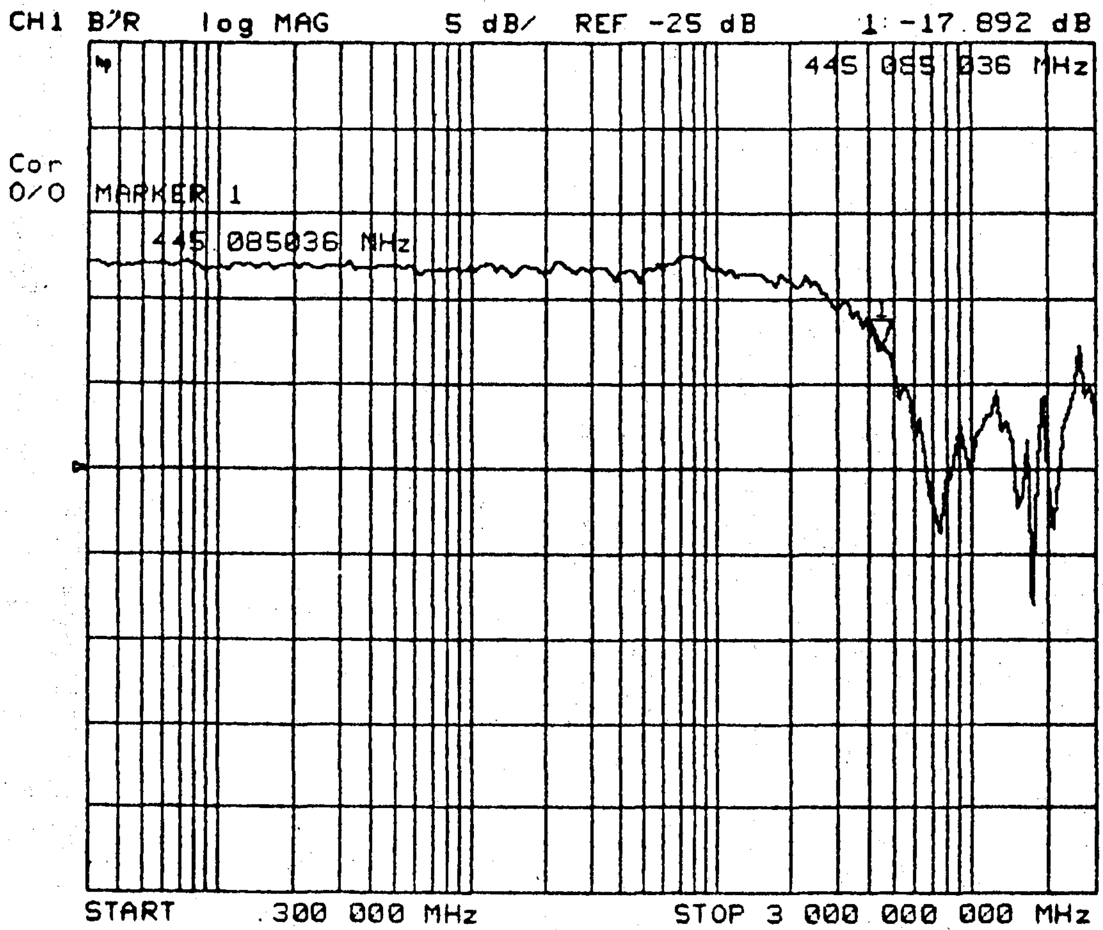


Fig. 3.10 Bandwidth vs additional biconic connectors at receiving end of the optical channel.

IV Conclusions.

The main goals of this research project were met. The KSC Fiber Optic Plant link was analyzed subject to ANSI X3T9.5 standards. Particular stress was placed on the system attenuation, and the bandwidth measurements for the multimode 50/125 micro meters fibers installed at KSC Plant. In order to assure quality measurements the optical source used in all tests were scrutinized using optical spectrum analyzer. In addition, a considerable amount of data was collected characterizing the biconic connectors and the effect they have on the overall channel transmission.The bandwidth of all 12 fiber optic test links in conjunction with a different interconnection of the biconic connectors was tested using the HP 8702 and 8703 Network analyzers (on a loan from Hewlett Packard). In conclusion, the current status of the KSC Fiber Optic Plant MMF mode will support the FDDI standard transmission data network. However, the effect of the biconic connectors, and the length of the KSC links, limits any future system expansion or improvements.

V. Future Research Suggestions.

In order to improve the performance of the FDDI at KSC the following is suggested:

5.1. Further analysis of the Biconic connectors in conjunction with large number of links at KSC.

5.2. Wave Form Fidelity

The pulse envelope measurement: the optical pulse shape output when measured through the Precision Test Fiber, shall fit within the boundaries of the pulse envelope in Fig. 5.1. For the rise and fall time measurements a minimum bandwidth range of 100 KHz to 750 MHz is required to evaluate the pulse envelope.

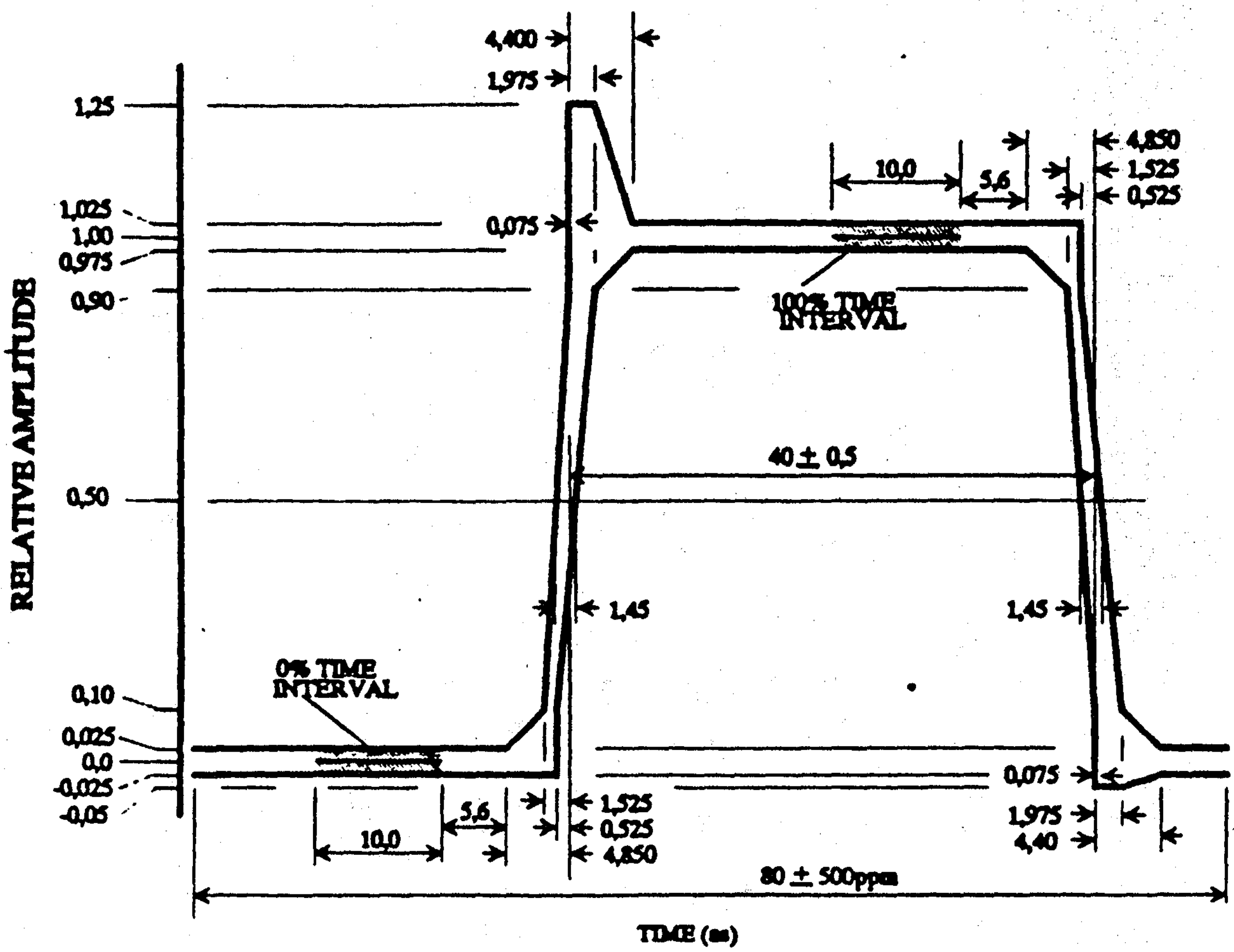


Fig.5.1 Pulse Envelope

5.3 The KSC link should be tested with FDDI Bridge FX 8210 and repeaters for a required EIA standard.

VI. Recommendation

All the bandwidth measurements for this project were done using a loaner from Hewlett Packard the Lightwave component analyzers (HP 8702 & 8703) with a Lightwave Source Module HP 83401 A and Lightwave receiver HP 83410 B with RF 11889 A interface kit. Therefore, it is recommended for the future measurements this equipment is placed permanently in the KSC Fiber Laboratory.

References:

1. Daniel Minoli, "Telecommunications Technology Handbook". Artech House 1991

2. Robert J. Ross. Fiber Optic Communications- Design Handbook Prentice Hall, 1990.

3. Chai Yeh " Handbook of Fiber Optics-theory & applications Academic Press 1990.

4. Serge UNGAR "Fiber Optics -theory & applications J. Wiley 1990.

5. Terry Edwards "Fiber-Optic Systems- Networks applications" J. Wiley 1989 .

6. N.B. Jones Jr. "Introduction to Optical Fibers Communication Systems. " HRW 1988.

7. Frederick C. Allard " Fiber Optics Handbook for scientist and engineers ". McGraw Hill 1989.

8. Amphenol Fiber Optic Products Catalog 1991

9. Hewlett Packard 1991 Tests and Measurements Catalogs

Appendix

A. Optical Time Domain Reflectometer TD-9960 Instrument Specifications.

1.2 Instrument Specifications

Data Acquisition Time (For 132 km display)	0.3 sec, Real Time 5 sec, Fast Scan 91 sec, Slow Scan Module Dependant
Readout Resolution	0.1 m, Module Dependant
Distance Scale Factors	4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, 4096, 8192, 16384 m/div. Module Dependant.
Vertical Scale Factors	0.25, 0.5, 1.0, 2.0, 4.0 dB/division
Vertical Resolution	0.01 dB
Vertical Linearity	0.04 dB/dB
Distance Accuracy	All modules except TD-860: ± 0.01 % of distance, ±4 m TD-860: ± 0.01 % of distance, ±1 m
CRT Display	7 inch, high-contrast green phosphor, raster scan, 512x480 resolution
Cursors	Dual independent with lock functions, automatic centering in expanded modes
Help Button	On line instructions and application notes which may be printed on the plotter
Video Output	NTSC Composite Video, (1V p-p 75 Ω) BNC Connector
Refractive Index	5 significant digits, range 1.0001 to 1.9999 digital entry, values retained in nonvolatile memory for each optical module.

Loss Modes	2 point- Relative loss between any two points in the fiber dB/km-Distance normalized fiber loss between any two points in the fiber Splice-Least square approximation of splice loss
Loss Resolution	0.01 dB
dB Accuracy	Digital logarithmic transformation, 0% temperature drift
Optical Modules Available (See Optical Module Specs.)	850 nm (± 30 nm) Multimode 1300 nm (± 30 nm) Multimode 1300 nm (± 30 nm) Single Mode 1520 nm (± 30 nm) Single Mode Dual 1300/1520 nm Single Mode
Interfaces	NTSC Composite Video Output (standard) RS-232C (DCE) Serial Interface (optional) GPIB (IEEE-488) Interface (optional)
Hardcopy Option	Plug-in 4 inch digital X-Y Plotter
Power Requirements	90-132 VAC, 47-63 Hz 180-260 VAC, 47-63 Hz 95 V.A. maximum
Dimensions	8" x 20.1" x 21.3"
Weight	38 pounds
Operating Temperature	-15 °C to 45 °C, ≤ 95 % Relative Humidity non-condensing (0 °C to 40 °C for rated specifications)
Storage Temperature	-20 °C to 60 °C
Laser Product Classification	21 CFR Class I, all optical modules

Accessories Provided	Power Cord Set of Fuses 2 m Fiber Optic Pigtail Instruction Manual

1.3 Optical Module Specifications

Optical Module	Wavelength Tolerance	Pulse Widths	Range For Scattering*	Maximum Range	Optical Connectors
TD-860 850 nm Multimode	± 30 nm	4 ns 40 ns	Min- 20 dB Typ- 23 dB	32 km	FC Standard Deutsch, SMA, Diamond, Biconic Available
TD-861 1300 nm Multimode	± 30 nm	10 ns 100 ns	Min- 17 dB Typ- 19 dB	64 km	FC Standard Deutsch, SMA Diamond, Biconic Available
TD-953 1300 nm Single Mode	± 30 nm	200 ns 630 ns 2 µs	Min- 20 dB Typ- 22 dB	132 km	PC Standard Biconic, D4, Diamond Availabl
TD-954 1520 nm Single Mode	± 30 nm	200 ns 630 ns 2 µs	Min- 18 dB Typ- 19 dB	132 km	PC Standard Biconic, D4, Diamond Availa
TD-955 1520/1300 Dual Single Mode	± 30 nm	200 ns 630 ns 2 µs	1300/1520nM Min- 20/17.5 dB Typ- 21/18.5 dB	132 km	PC Standard Biconic, D4, Diamond Availabl
TD-963 1300 nm Hi Res Single Mode	± 30 nm	25 ns 170 ns 1 µs	1300 nM Min- 16 dB Typ- 18 dB	64 km	PC Standard Biconic Available

Laser Safety Classification: 21 CFR Class 1

* Single-way dynamic range for a Signal to Noise ratio of 1.

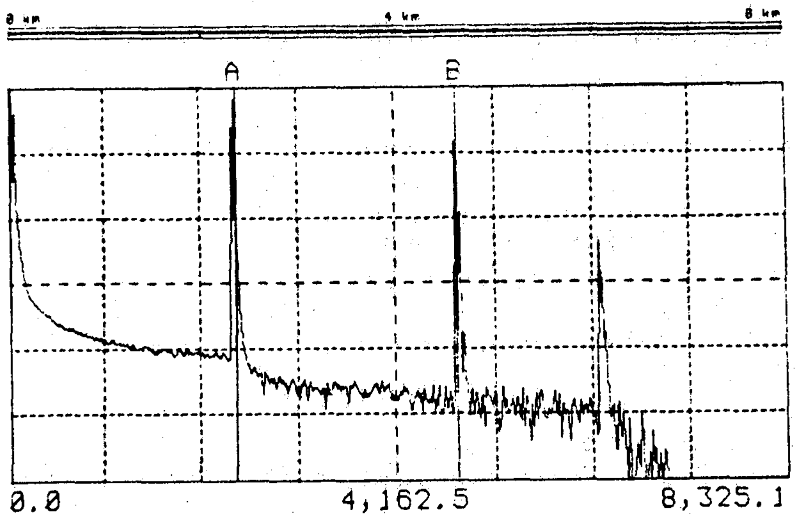
1.4 Optional Equipment Available

TD-952	Fully buffered 4 inch digital X-Y Plotter, front panel plug-in.
TD-952C	4 color version of TD-952.
TD-232	RS-232C (DCE) Serial Interface for driving external HP-GL Compatible plotters. 50 to 19.2 k baud. Front panel plug-in.
TD-488	GPIB Interface for computer control. Functions: SH1, AH1, T5, L4, SR0, PP0, DC0, DT0, C0. Factory installed.
TD-910	Bare Fiber Adapter. Multimode.
TD-914	Bare Fiber Adapter. 1300 nm Single mode.
TD-960	Rugged Transit Case.

B. Attenuation Loss vs Fiber Link Length

B.1. Channels 3-12.

CH. 3-4



↑ 4.0 dB/div 1,040.6 m/div →

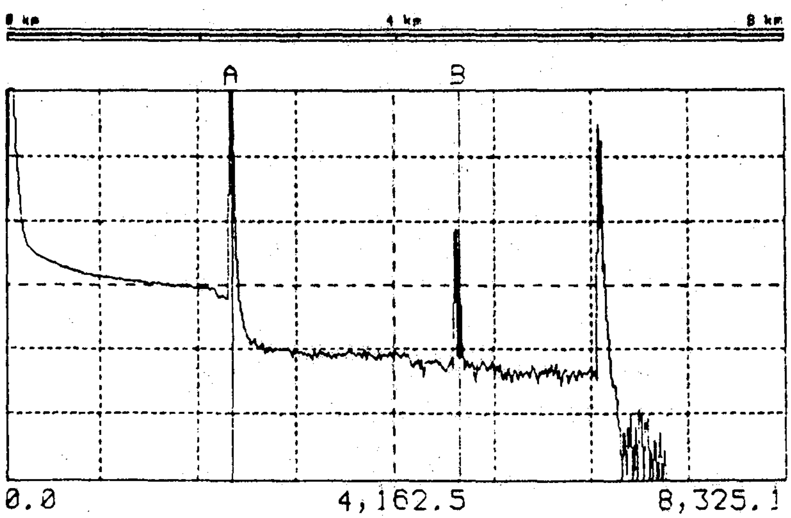
A= 2,439.0 m INDEX: 1.4750

B= 4,812.9 m λ: 1300 nm

A→B= 2,373.9 m dB/km LOSS: 2.86 dB

Optics: TD-861 1300nm HR Multimode
Scan Mode: SLOW
Pulse Width: SHORT

Ch. 5-6



↑ 4.0 dB/div 1,040.6 m/div →

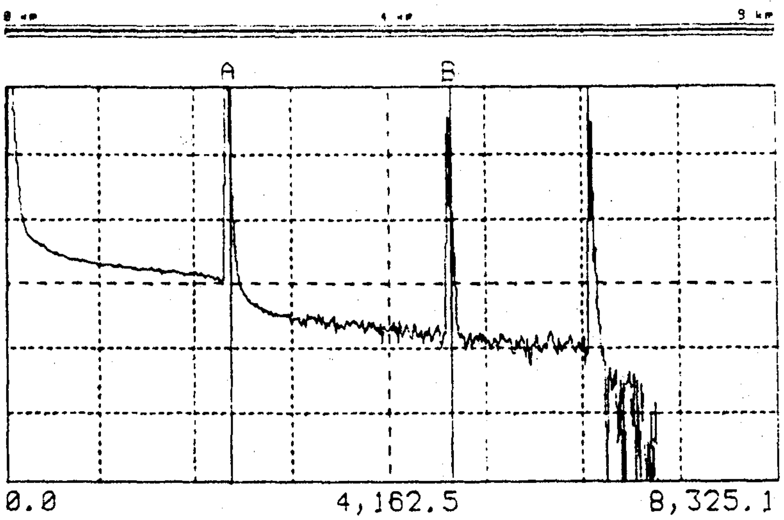
A= 2,428.4 m INDEX: 1.4750

B= 4,845.4 m λ: 1300 nm

A→B= 2,417.0 m 2-POINT LOSS: 9.74 dB

Optics: TD-861 1300nm HR Multimode
Scan Mode: INCOMPLETE
Pulse Width: LONG

Ch. 7-8

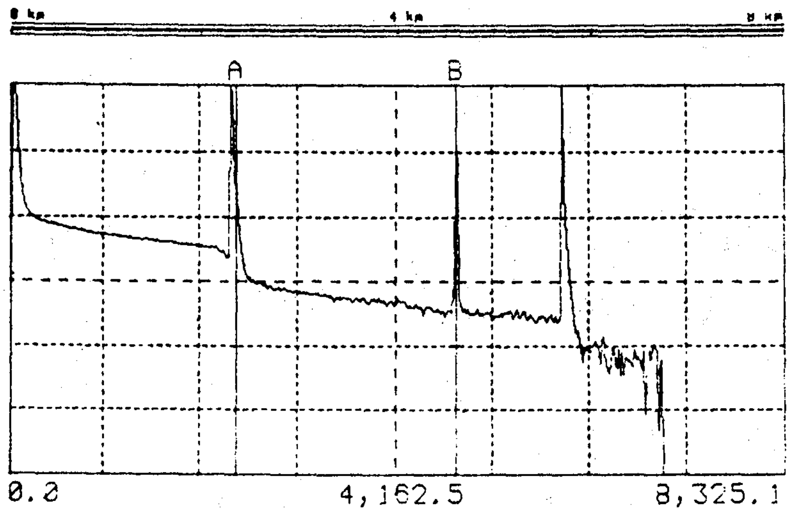


↑ 4.0 dB/div 1,040.6 m/div →

A= 2,461.0 m INDEX: 1.4750
B= 4,845.4 m λ: 1300 nm
A→B= 2,384.5 m dB/km LOSS: 1.51 dB

Optics: TD-861 1300nm HR Multimode
Scan Mode: INCOMPLETE
Pulse Width: LONG

Ch.9-10

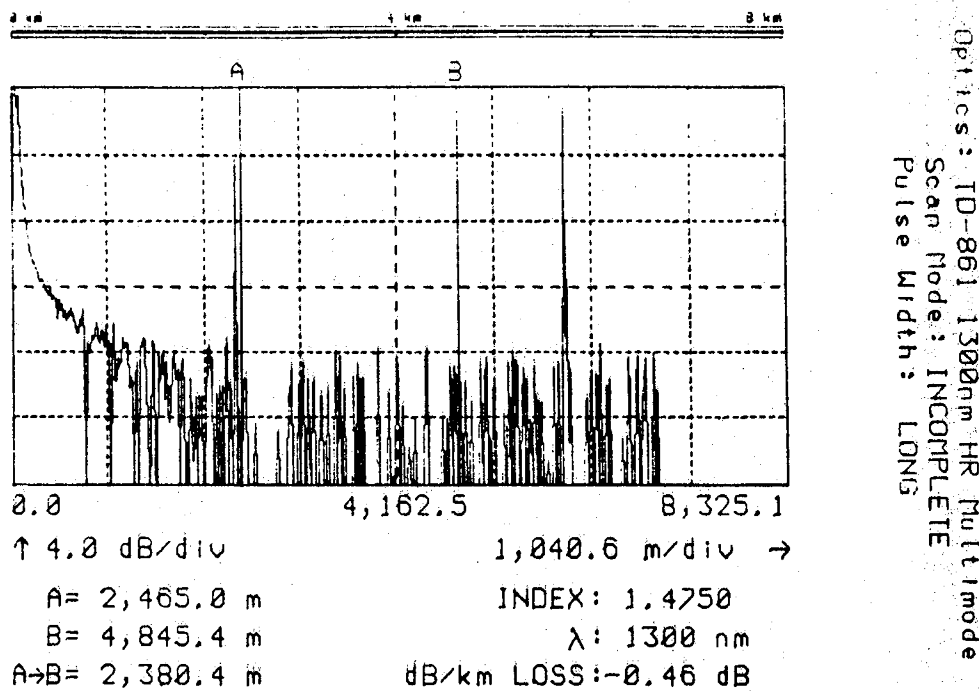


↑ 4.0 dB/div 1,040.6 m/div →

A= 2,465.0 m INDEX: 1.4750
B= 4,845.4 m λ: 1300 nm
A→B= 2,380.4 m dB/km LOSS: 0.19 dB

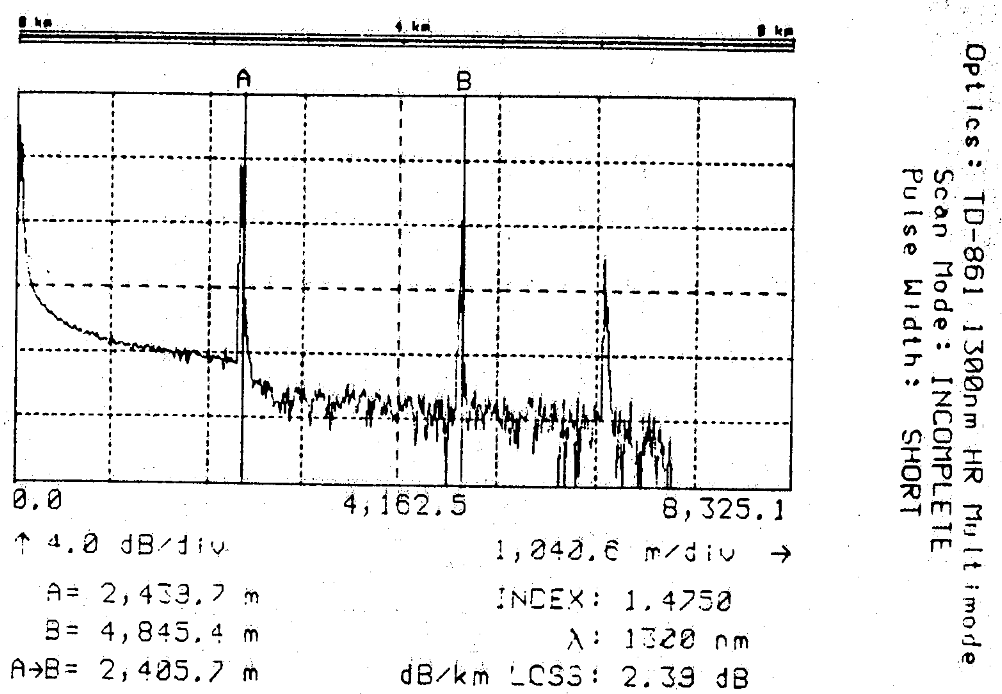
Optics: TD-861 1300nm HR Multimode
Scan Mode: INCOMPLETE
Pulse Width: LONG

Ch. 11-12

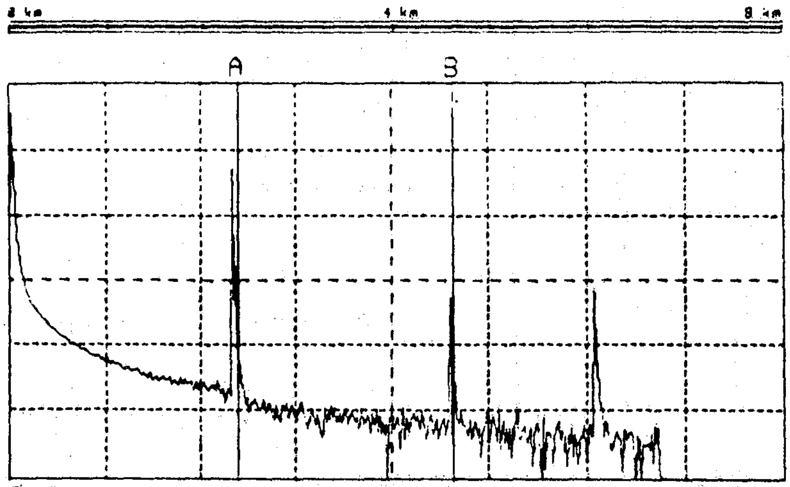


B.2. Channels 12-3

Ch.4-3



Ch. 6-5



0.0 4,162.5 8,325.1

↑ 4.0 dB/div 1,040.6 m/div →

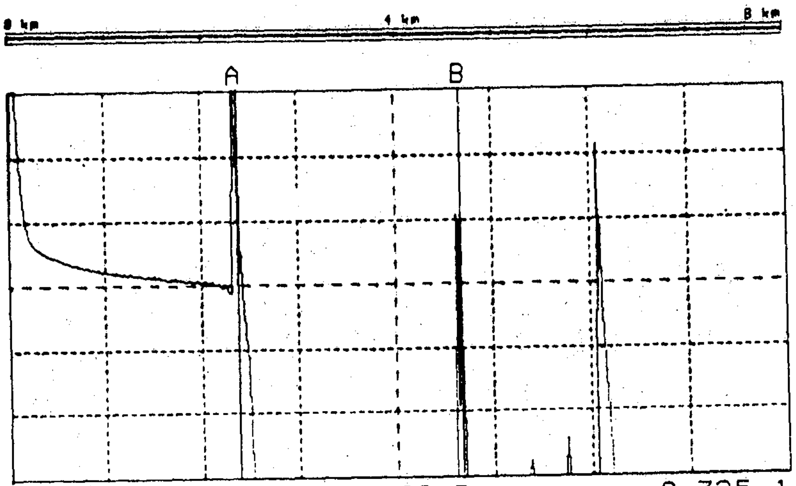
A= 2,455.2 m INDEX: 1.4750

B= 4,829.2 m λ: 1300 nm

A→B= 2,373.9 m dB/km LOSS: 2.90 dB

Optics: TD-861 1300nm HR Multimode
Scan Mode: INCOMPLETE
Pulse Width: SHORT

Ch. 8-7



0.0 4,162.5 8,325.1

↑ 4.0 dB/div 1,040.6 m/div →

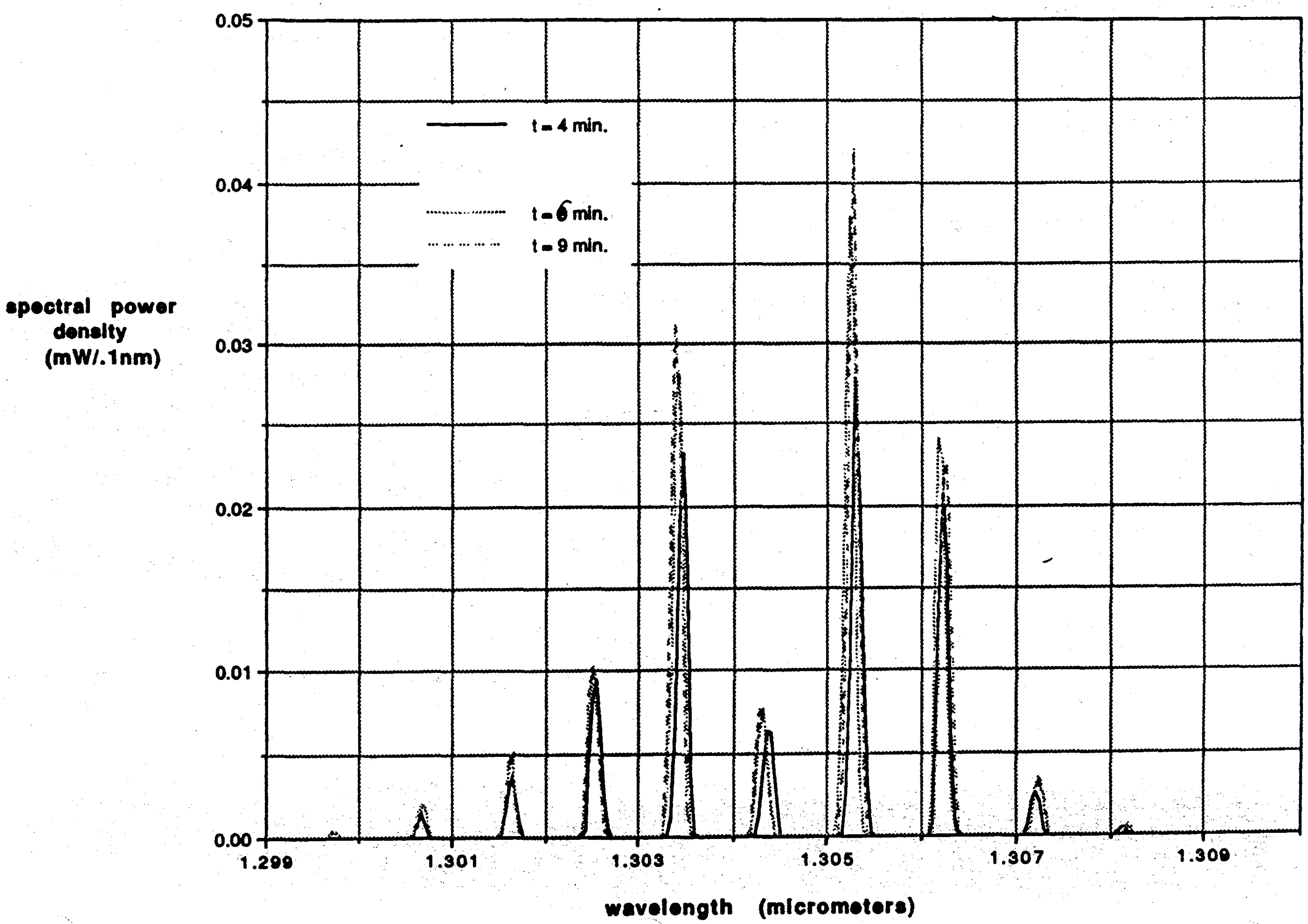
A= 2,439.7 m INDEX: 1.4750

B= 4,861.7 m λ: 1300 nm

A→B= 2,422.0 m 2-POINT LOSS:15.02 dB

Optics: TD-861 1300nm HR Multimode
Scan Mode: INCOMPLETE
Pulse Width: LONG

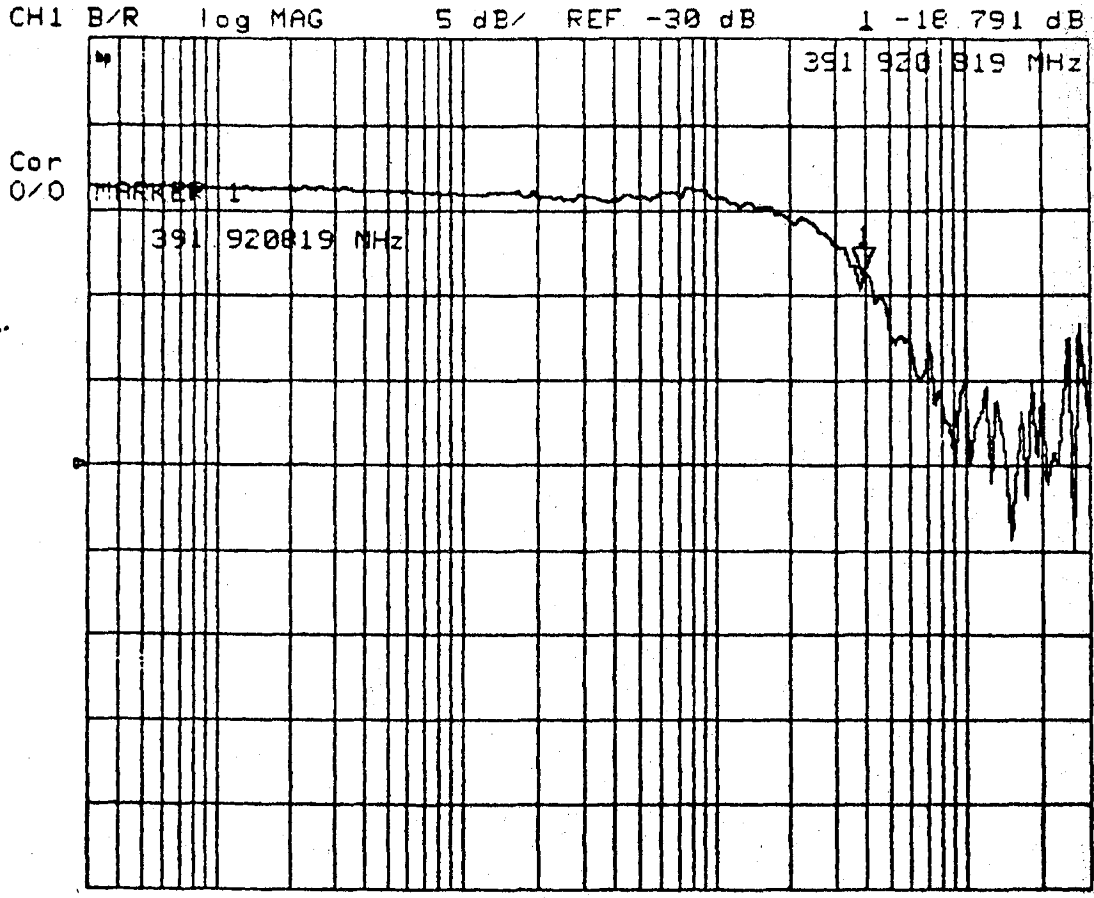
Optical Spectrum of HP 8703A After Cold Start (7/8/91)



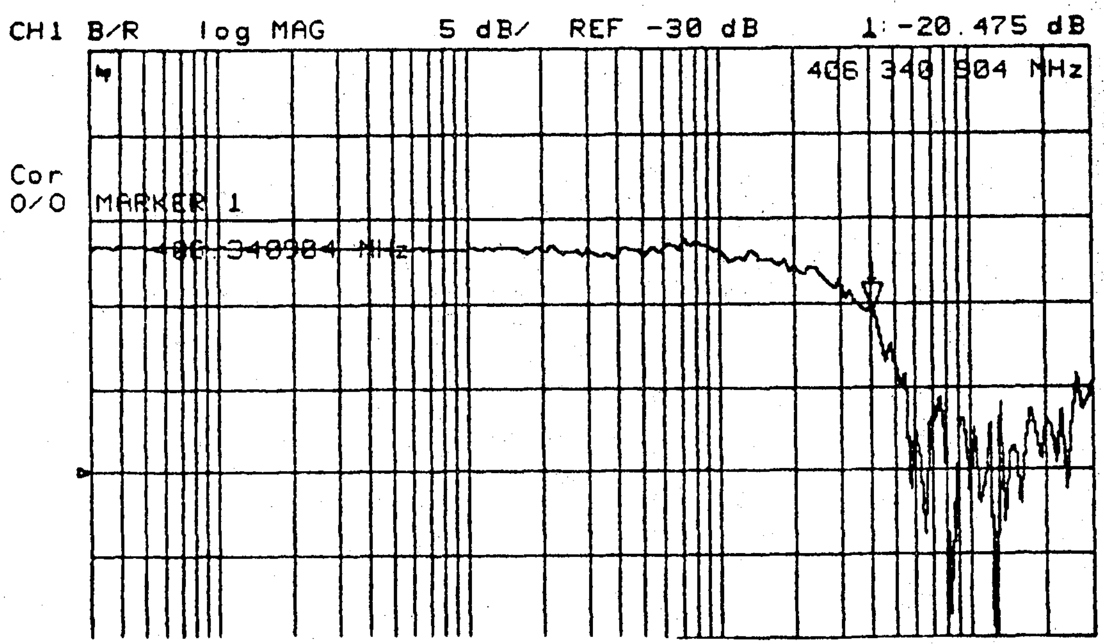
C. Instability of HP Laser Source as a function of time.

D. Gain vs Frequency for the KSC Links 3-12

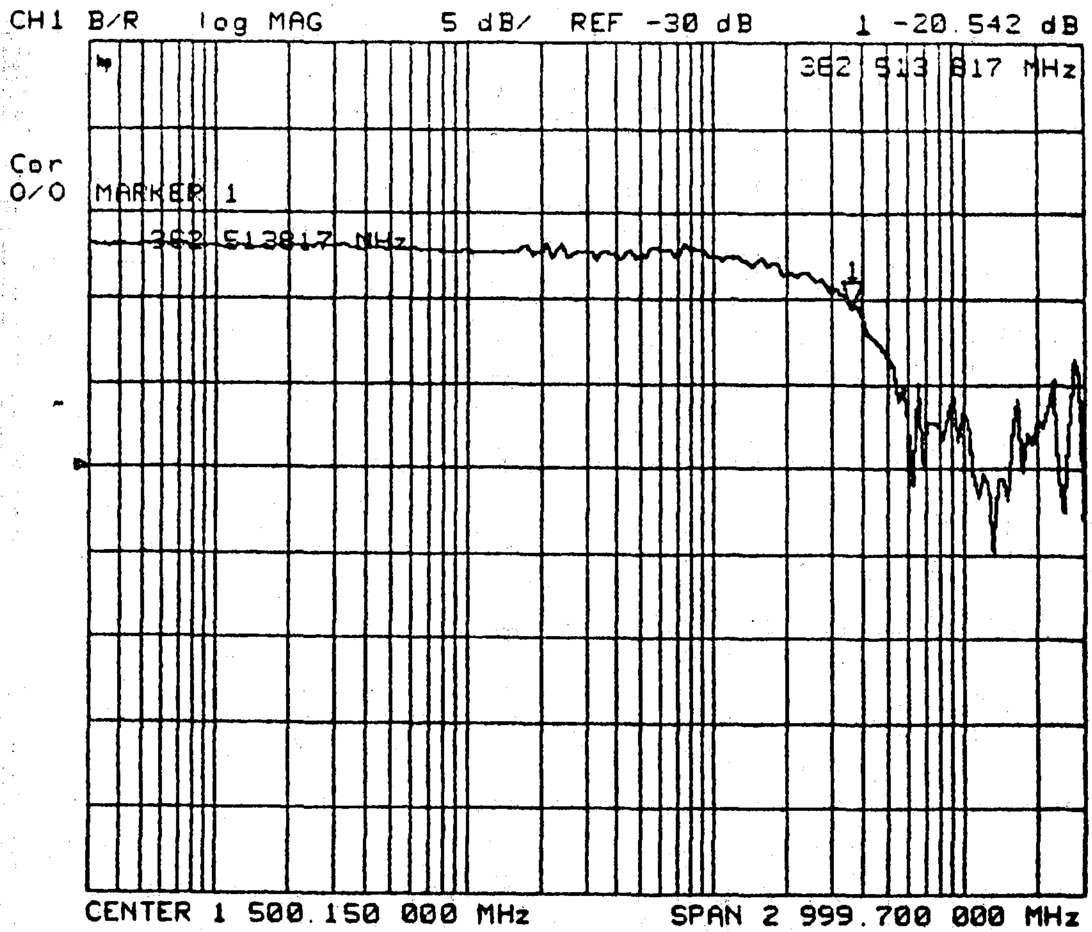
Ch. 3-4



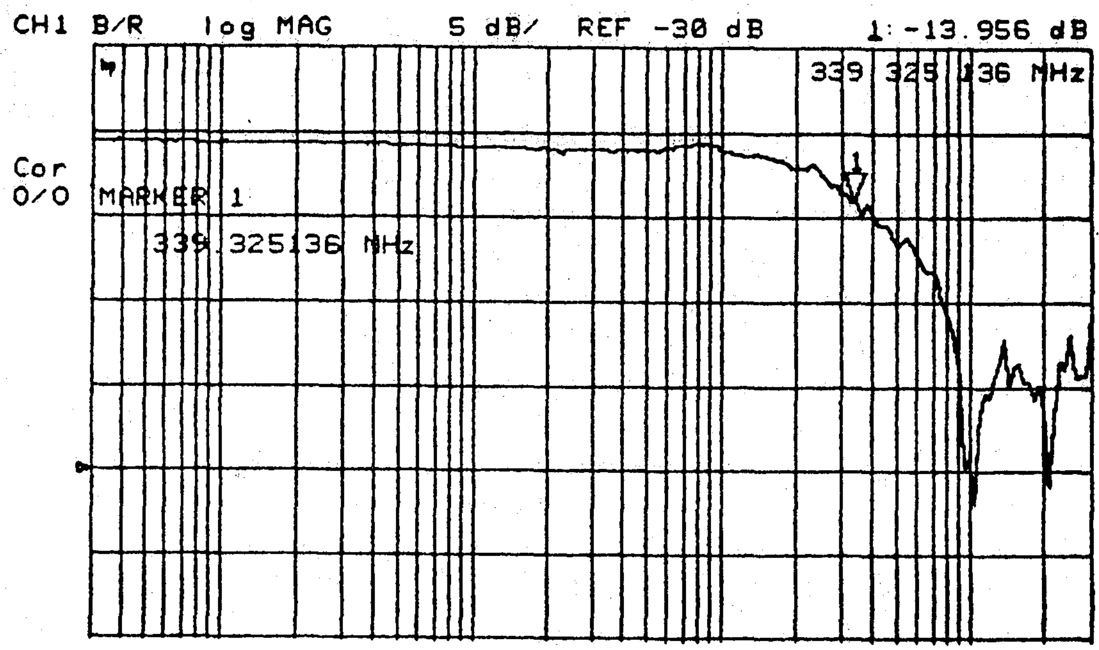
Ch. 5-6



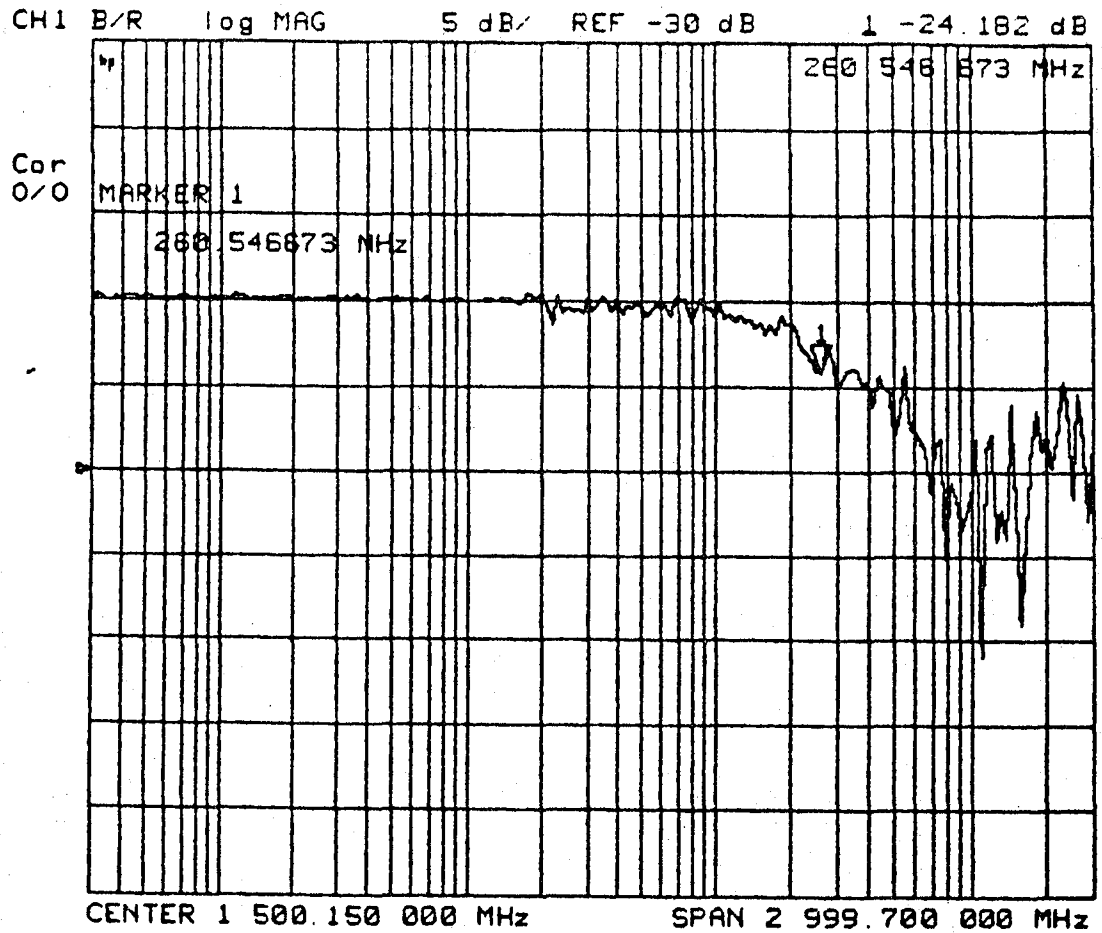
Ch. 7-8


CH1 B/R log MAG 5 dB/ REF -30 dB 1 -20.542 dB
382 513 817 MHz
Cor
0/0
MARKER 1
382.513817 MHz
CENTER 1 500.150 000 MHz
SPAN 2 999.700 000 MHz

Ch. 9-10


CH1 B/R log MAG 5 dB/ REF -30 dB 1: -13.956 dB
339 325 136 MHz
Cor
0/0
MARKER 1
339.325136 MHz

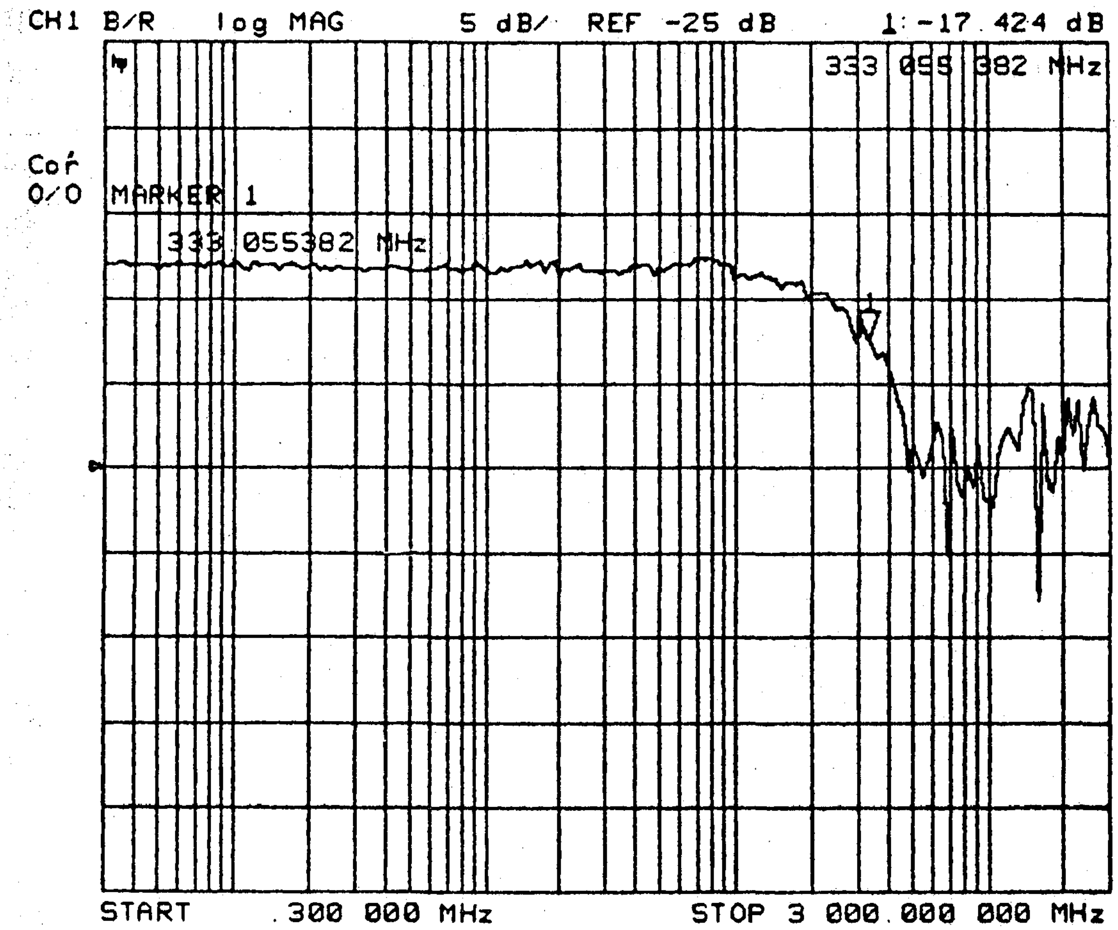
Ch.11-12


CH1 B/R log MAG 5 dB/ REF -30 dB 1 -24.182 dB
260 546 873 MHz
Cor
O/O
MARKER 1
260.546873 MHz
CENTER 1 500.150 000 MHz
SPAN 2 999.700 000 MHz

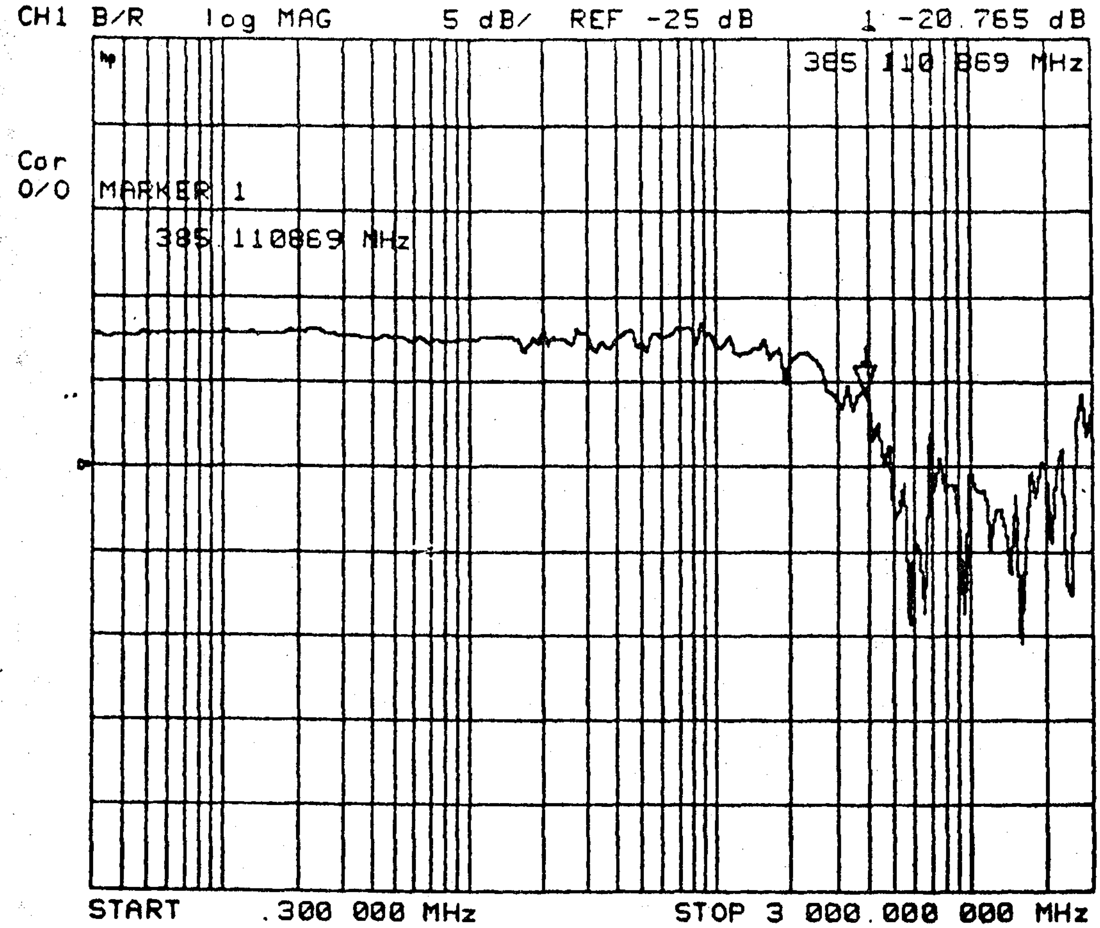
Appendix E

Effect of a biconic connectots on the KSC Fiber Plant placed at the detector end for Limks 3-12

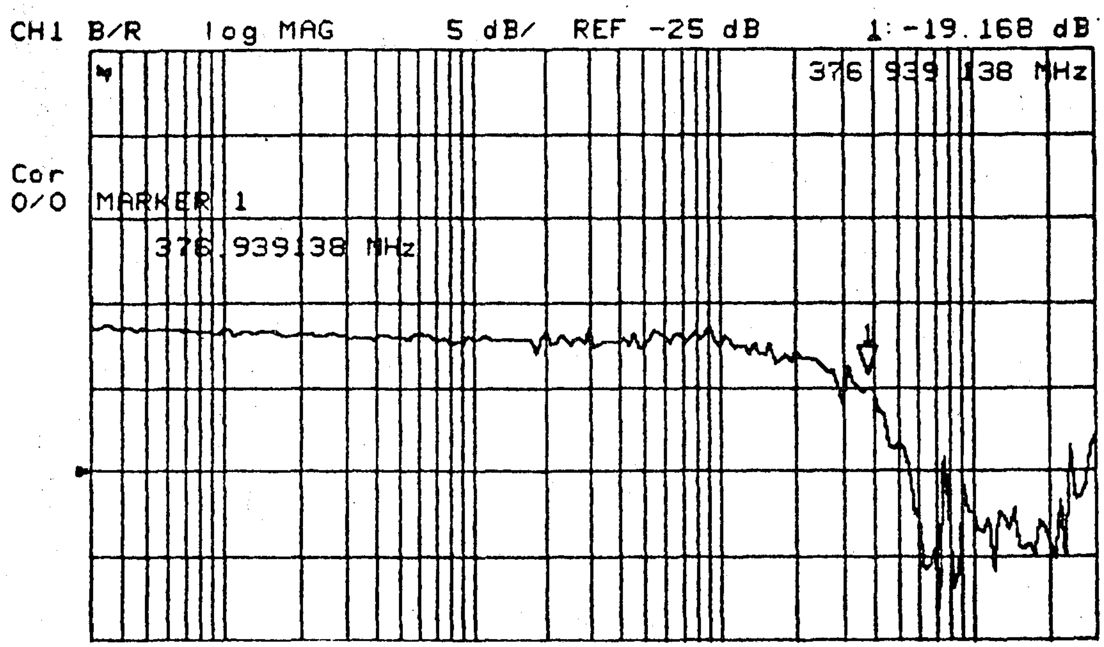
Ch. 3-4



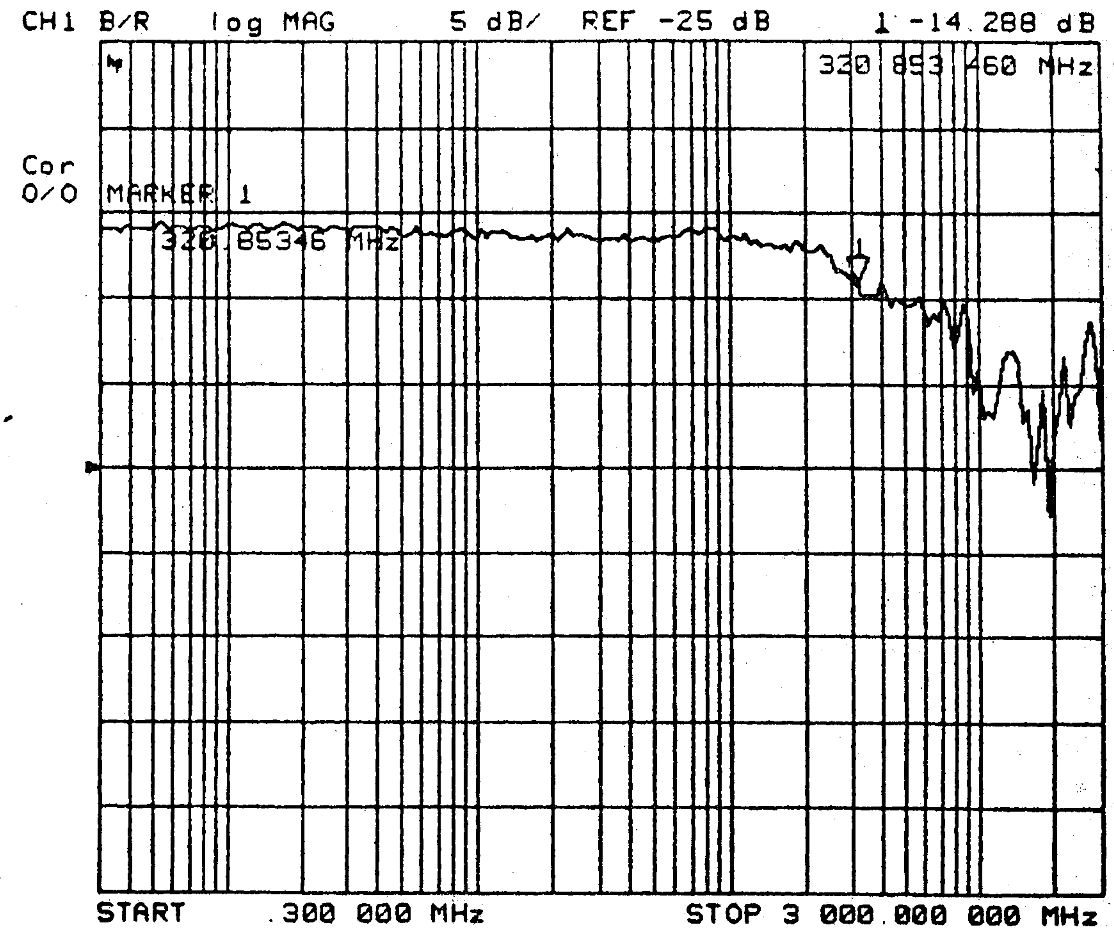
Ch. 5-6 plus additional biconic connectors



Ch. 7-8



Ch. 9-10



Ch.11-12