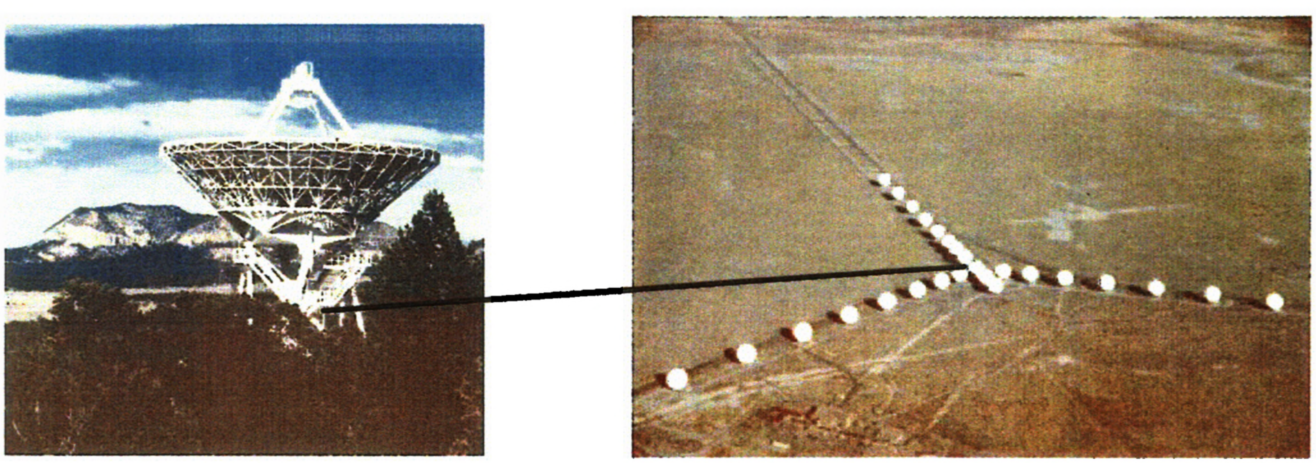
VLA - Pie Town Link

PROJECT HANDBOOK

VLA TECHNICAL REFERENCE No. 77

Project Engineer Ron Beresford

Date 6th Jan 2000



1. Introduction

The VLA to PT link project encompasses a 104km fiber optic link between NRAO's VLA and Pie Town VLBA antenna , additional RF conversion electronics , monitor and control , and increased delays for all VLA antennas.

Optical Wavelength Division Multiplexing (WDM) is used to transmit mixed signal bidirectional optical signals over one standard singlemode fiber core. A high power unidirectional externally modulated optical carrier at λ_1 is used to provide the high dynamic range IF analog transmission from PT to the VLA. Lower power directly modulated optical signals at λ_2 and λ_3 ,from opposite ends of the fiber provide a bidirectional digital communications path for monitor and control of the PT link equipment rack between sites.

Using the VLA-PT link the angular resolution of the VLA is effectively doubled while maintaining the full sensitivity of the 27 antenna VLA.

The initial concept of connecting the Pie Town VLBA antenna into the VLA as a phased array element of the VLA has a 10 year history.

The final location of the "PT antenna" , a 52km EW baseline from the center of the VLA , was selected to provide UV plane coverage intermediate to the VLA extended A configuration and the VLBA or VLBI configurations. Sub arcsec angular resolution at Q band is possible.

Although sometimes a contentious issue the PT/VLA link is primarily an enhancement to the VLA and not the VLBA. Most scientific benefit would occur with PT in the VLA during A array , nominally a consecutive block of time 3 months every 18 months.

Fortuitously the Western New Mexico Telephone company had installed primary rate fiber based transports as part of the public switched network over much of Southwest New Mexico. By fusion splicing together several singlemode fiber enroute locations a PT to VLA point to point dark fiber 104kms in length was established. NRAO did this for two fibers ,for the prototyping phase of the project ,completing OTDR analysis in March 98.

Initial design work and feasibility studies were commenced in the later half of 97 . Fiber rental agreements with WNMT to be exercised when the system becomes fully operational ,and the NSF project financing (a sum of $666K) was finalized around this time as well.

Fiber optics is an obvious choice for interconnecting phased array antennas ,gaining wide acceptance due to the low optical loss , typically less than 0.2dB/km @1550nm and the enormous bandwidth potential (1 Tbit/sec/fiber) of multiwavelength singlemode systems.

The PT/VLA project was to be the longest span fiber optic link based radioastromony project todate.
The BL (gain bandwidth product) of the analog transmission alone exceeds 20GHz.kms.
Exceeding the BL product of other predecessors such as the ATNF Compact Array by an order of magnitude.

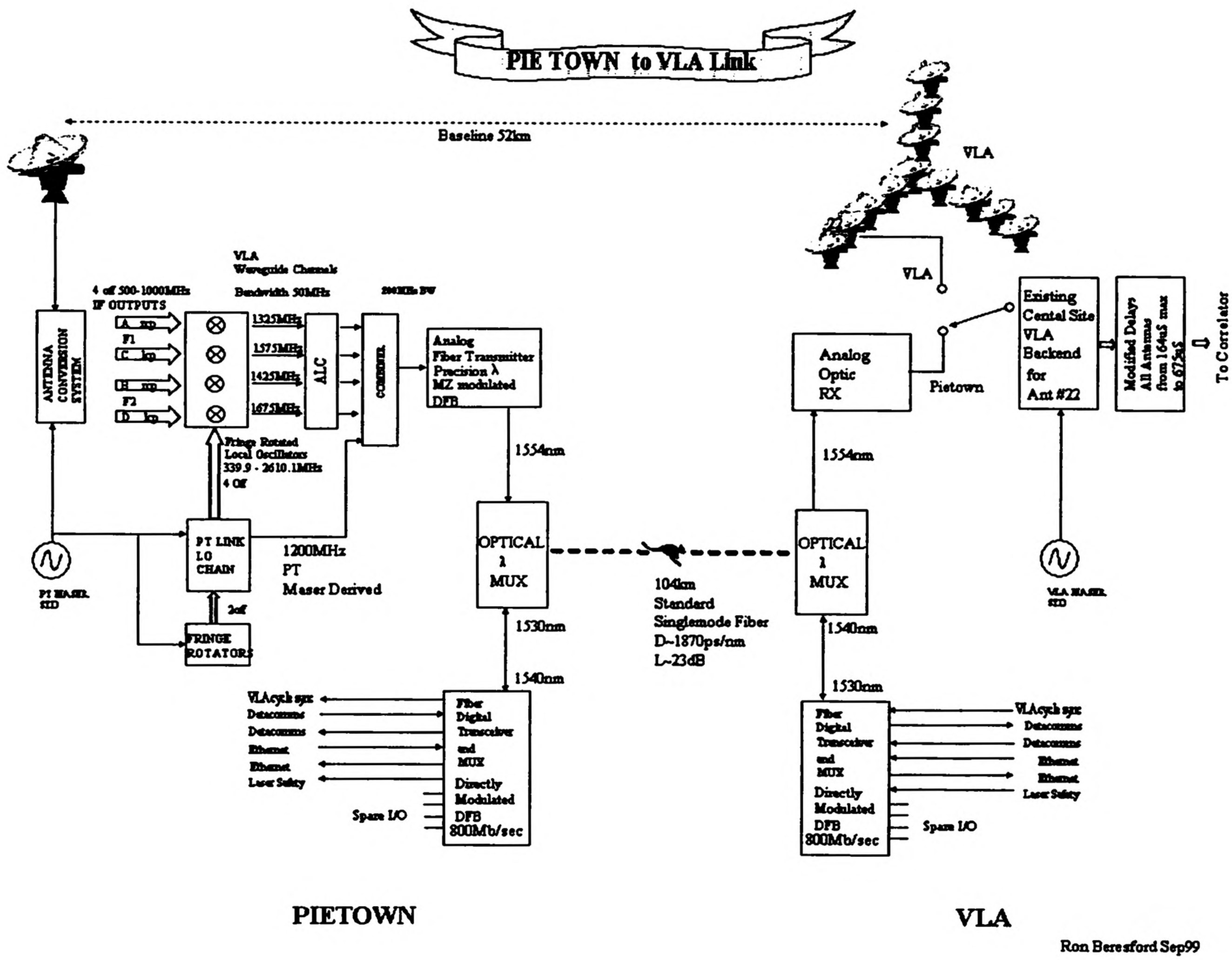
Fiber optic communications is a rapidly evolving field driven by the large information carrying needs of the telecommunications sector. The PT/VLA link was to use the most contemporary techniques and to a degree serve as a demonstration project for other radio astronomy endeavors such as the A++ VLA array using several additional 100km+ outrigger antennas to the VLA , the VLA upgrade replacing the current metallic Sumitomo circular waveguide ,the Atacama Large Millimiter Array in Chile and the LOFAR low frequency array to name but a few.

By December of 98 finges between PT and the VLA were obtained using a 3 antenna array and a single IF.

By September of 99 fringes between PT and the VLA were obtained on both left and right circular polarization on all bands common to the PT and VLA receiving systems. using all 26 VLA antennas with PT substituting for antenna 27. Some science was done.
The final 4IF single fiber architecture was implemented in Oct99.

Although fiber optics makes the PT link a reality considerable effort was also required in the RF conversion subsytems ,correlator delay subsystems and control software.

Approximately 4 manyears of hardware development and 2 manyears of software development was required.



PIE TOWN LINK ELECTRONICS

The PT link provides the interface between the VLBA antenna and the VLA electronics for all common receiving bands , P band (327MHz) through to Q band (45GHz) for the sites.

The four PT VLBA outputs ,Frequency 1 (right and left circular polarization) and Frequency 2 (right and left circular polarization) ,each 500-1000MHz is upconverted to standard 50MHz wide VLA channel slots of A 1325MHz,C 1575MHz , B 1425MHz and D 1675MHz respectively.

A triple balanced conversion stage for each channel is made possible by L6 local oscillators in the range 339.9 to 2610.1MHz , permitting both USB and LSB conversion sense on each IF for complete VLA compatibility. Each frequency pair of L6's are driven by a common L7 fringe rotator.

IF outputs are automatic level controlled and combined together with a PT Maser derived 1200MHz reference to then modulate the RF fiber optic transmitter.

The fiber optic system is a wavelength division multiplexed (WDM) design comprising three wavelengths operating over a single core of standard high dispersion singlemode fiber , 104kms in length and 1800ps/nm dispersion. Extensive use is made of current telecommunication components and techniques for the low optical loss (0.2dB/km) 1550nm window.

A high power , high dynamic range ,externally modulated (Mach-Zehnder) direct detection intensity unidirectional RF channel from PT to the VLA at 1554 nm wavelength transports the composite 200MHz IF output. The use of precision PID thermal and required bias control enable ultra high CW wavelength stability for minimizing dispersive effects on phase and the optical spectrum characteristics for suppression of Stimulated Brillouin Scatter in the presence of the 10mW CW high optical launch power to maintain 20dB SNR per IF.

An 800Mbit/sec (nominally configured to 200Mbit/sec) serial bit rate ,bidirectional direct modulated digital system between sites at 1530 and 1535nm provides synchronization of the PT noise diode , fringe rotation as well as connectivity to the VLA Monitor and Control system. The 200Mbit/sec is generated by a 20 bit wide bus clocked at 10MHz using Hewlett Packard "G link" LSI transmit and receive chipset pairs. Digital data is fed asynchronously through the system ,enabling versatility with a number of input and output signals of various clock origins.

Exceptionally low optical channel crosstalk is achieved with networks comprising cascadable dichroic thin film interference filters.

The PT analog IF data and 1200MHz tone is recovered from the analog link photodiode. The PT 1200MHz is compared with the VLA 1200MHz master LO for 1st order phase reckoning. The 4 analog IF's are then converted to baseband and digitized in standard VLA samplers.

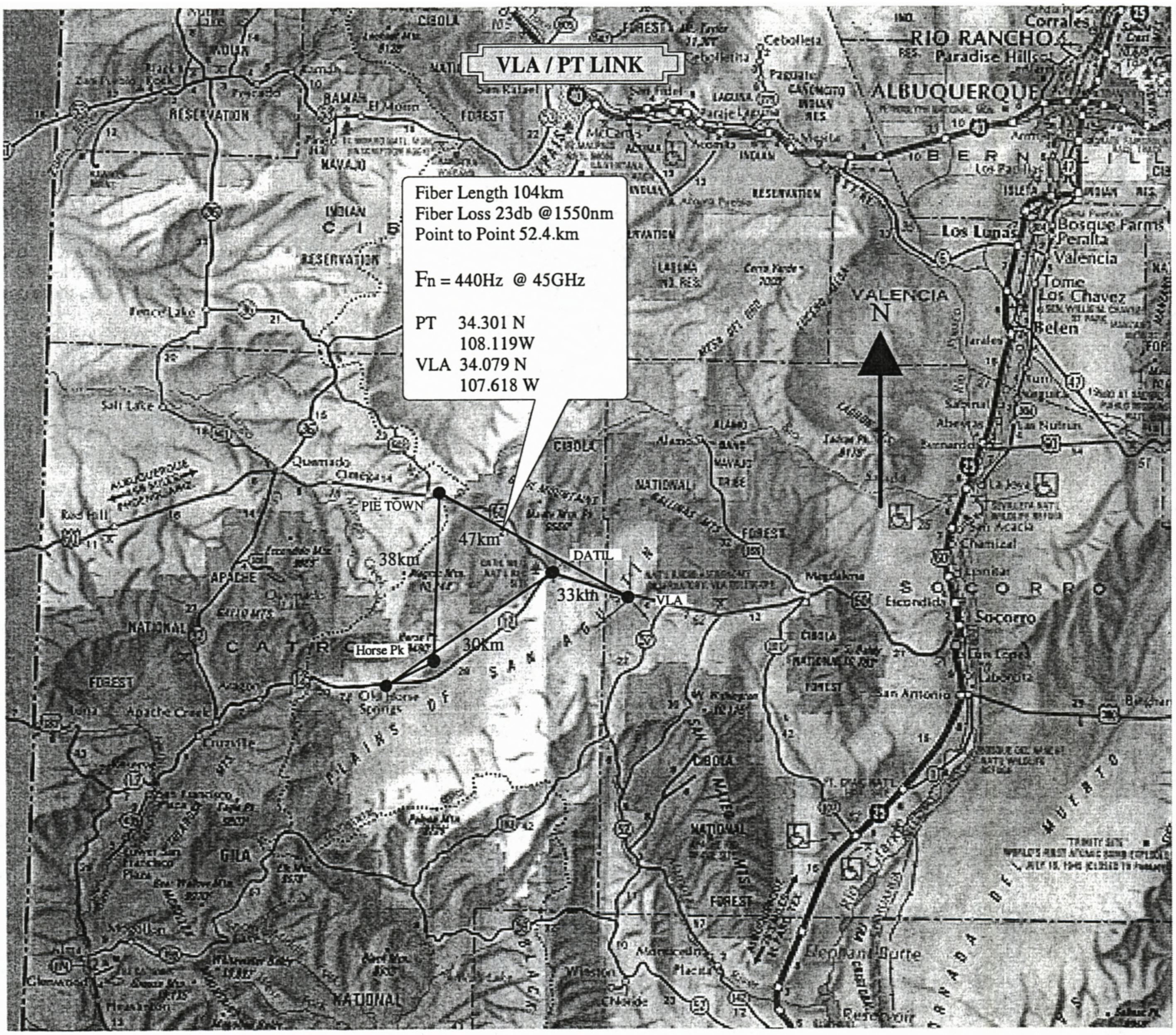
To accommodate the extra delays of the 52km baseline the new delay cards for each IF can be programmed to a maximum of 819.2µS using larger FIFO memory and XYLINX control on a "piggy back" PCB assembly inserted into the 108 standard VLA delay cards.

Where possible in the project ,reuse of existing VLA hardware and software has been made. In particular the decision to substitute the 5 west antenna by "switching in " the PT antenna in lieu and use the existing VLA "D rack" backend electronics minimized hardware construction.

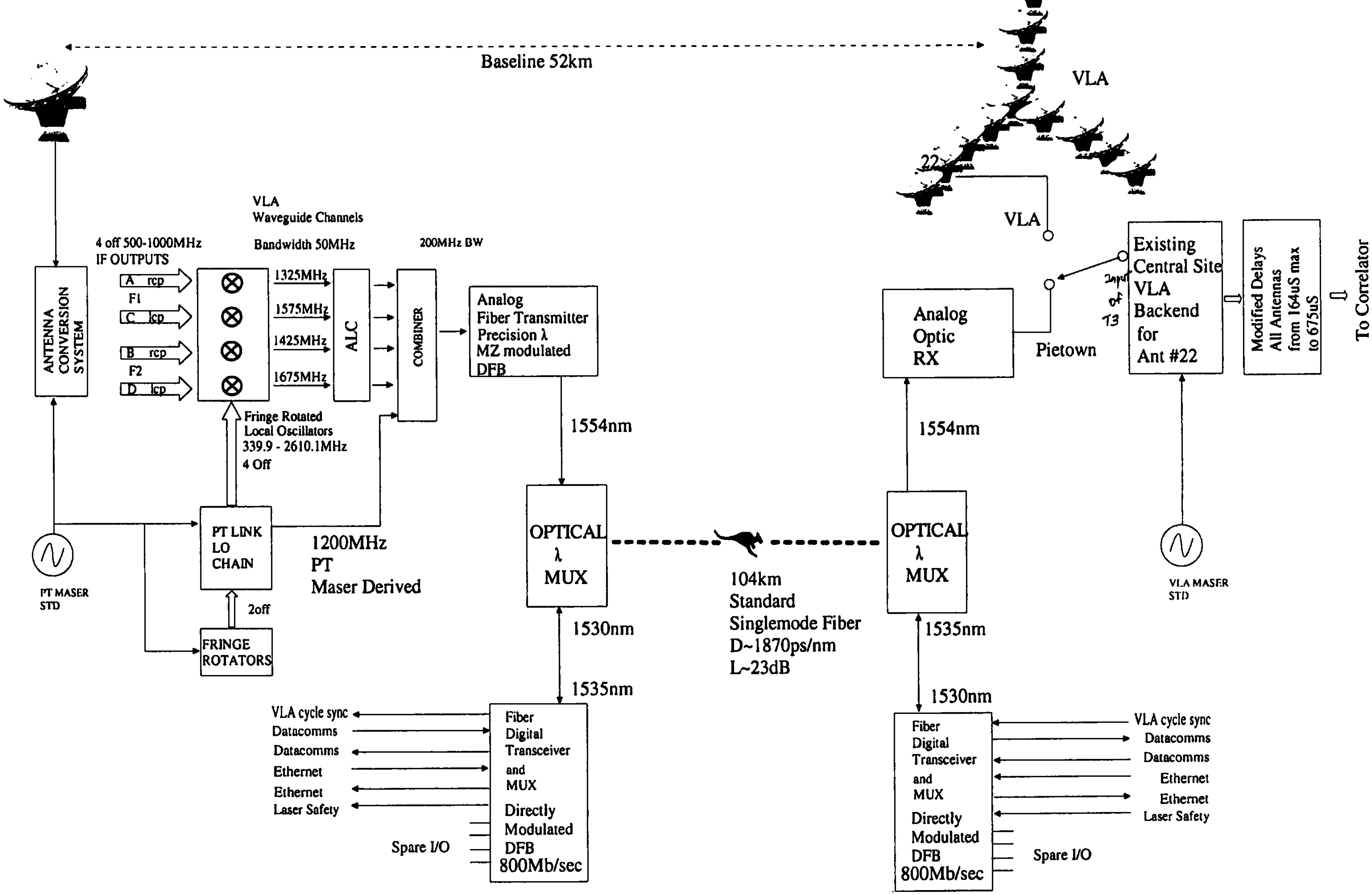
Early imaging work with the PT antenna linked to the VLA has revealed twice VLA resolution with the sensitivity of the VLA.

Ron Beresford 28 Dec 99

map.drw


VLA / PT LINK
Fiber Length 104km
Fiber Loss 23db @1550nm
Point to Point 52.4.km
Fn = 440Hz @ 45GHz
PT 34.301 N
108.119W
VLA 34.079 N
107.618 W
PIE TOWN
47km
38km
DATIL
33kth
VLA
Horse Pk
30km
N
RIO RANCHO
ALBUQUERQUE
VALENCIA
SOCORRO

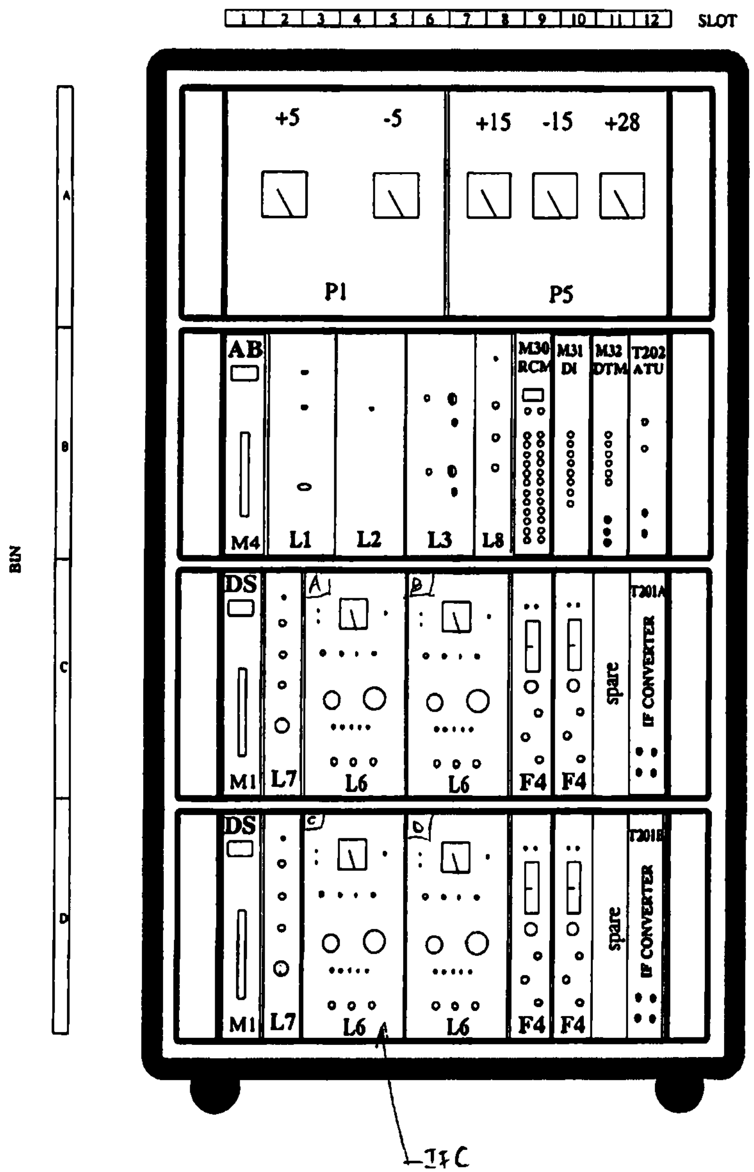
PIE TOWN to VLA Link



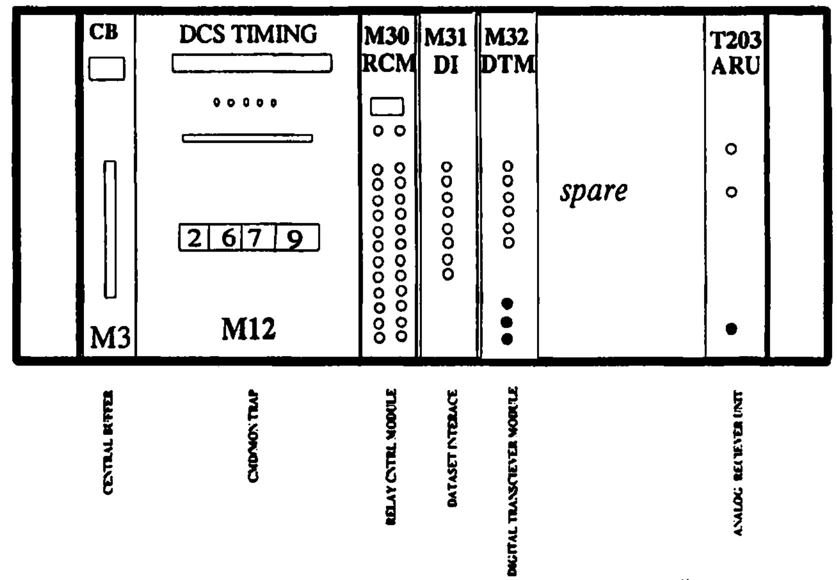
PIETOWN **VLA**

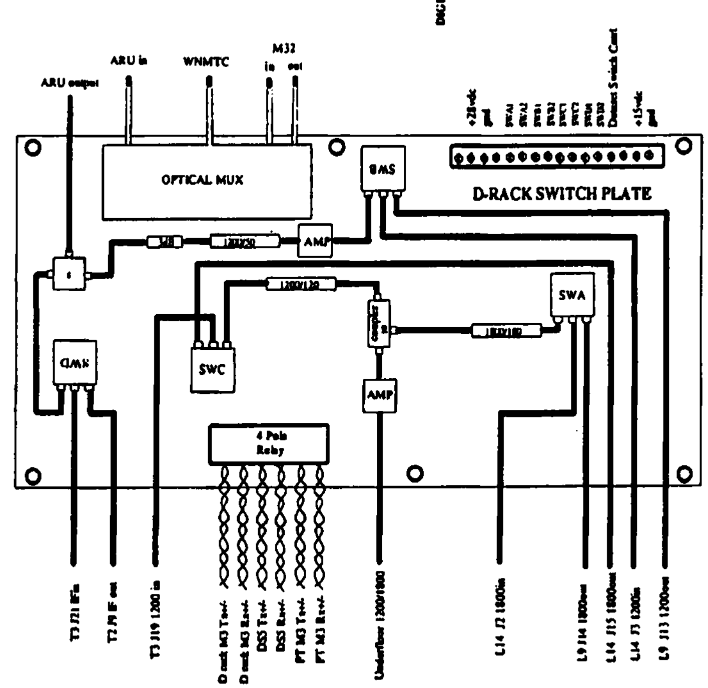
Ron Beresford Dec99

VLA / PT LINK
INTERFACE EQUIPMENT RACK
VLBA SITE



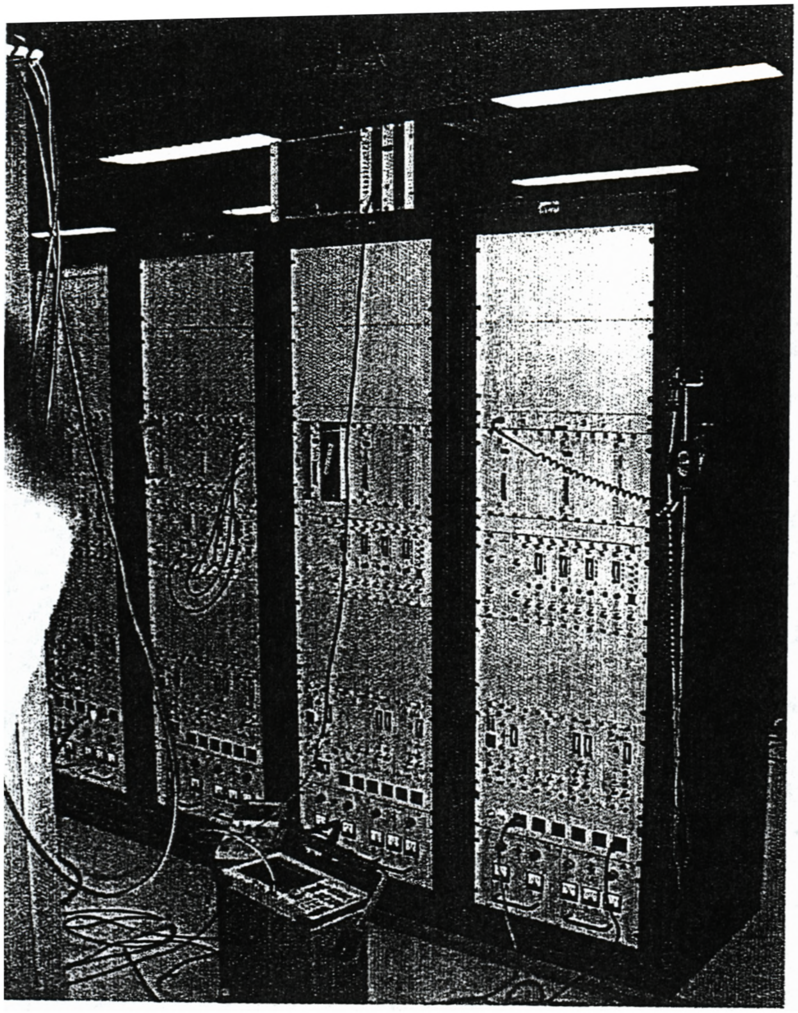
VLA / PT LINK
INTERFACE EQUIPMENT BIN
VLA SITE

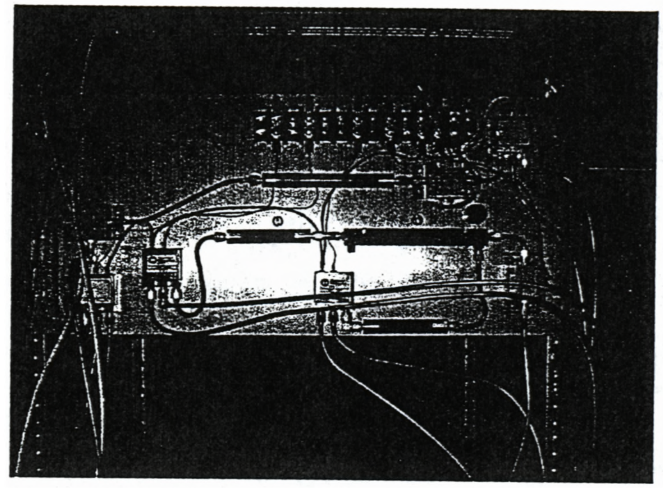




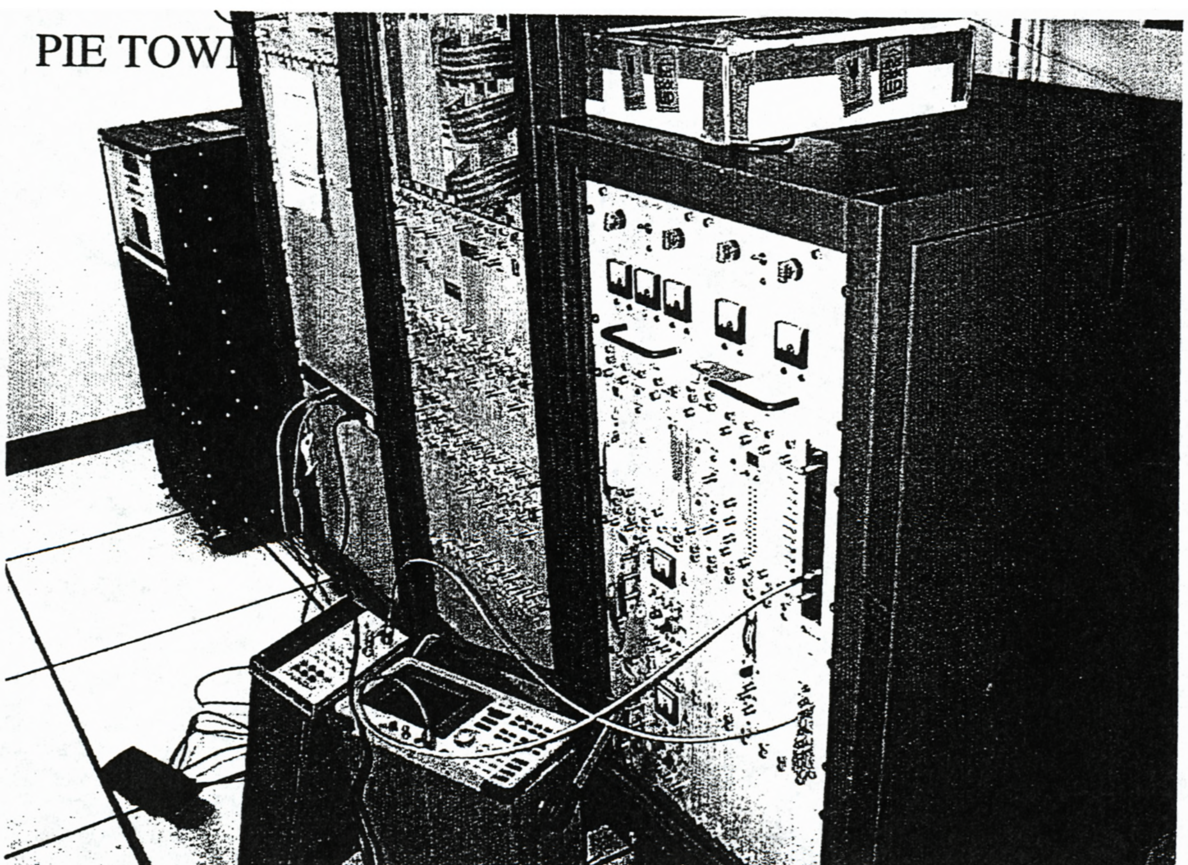
▢ = under development

Ken Herreford 8 July 98



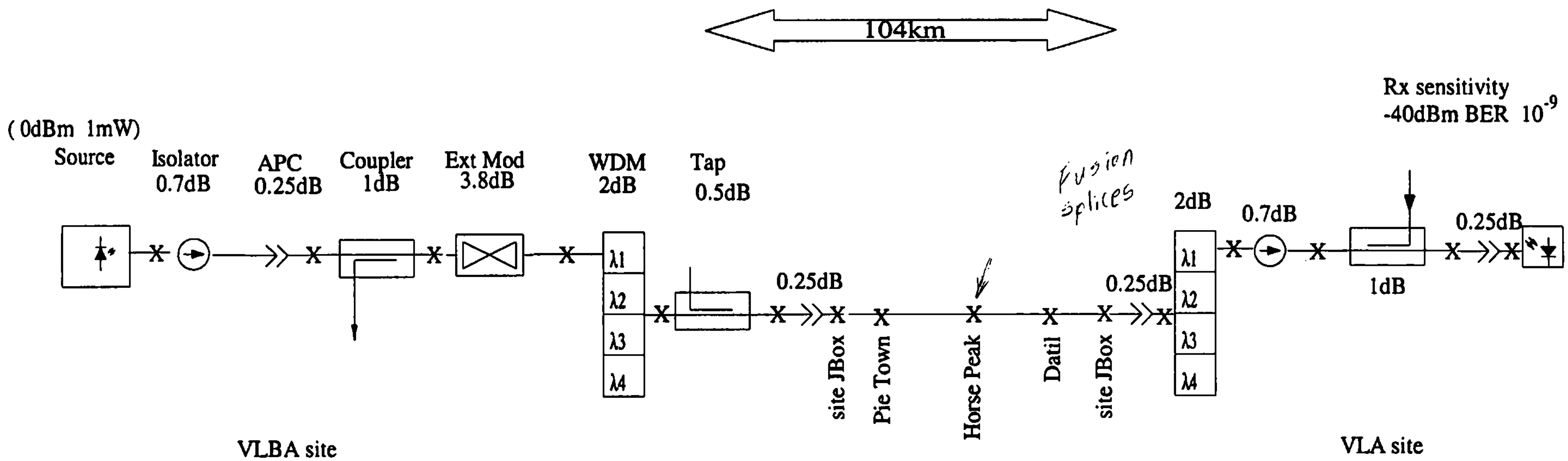


PIE TOW



pt loss.drw

PIE TOWN -VLA
OPTICAL BUDGET



Component Loss = 12.7 dB

Splice Loss = 1.6dB @ 0.1dB join

Cable Loss @ 1550nm 0.19dB/Km = 19.7dB
@ 1310nm 0.32dB/km = 33.2 dB

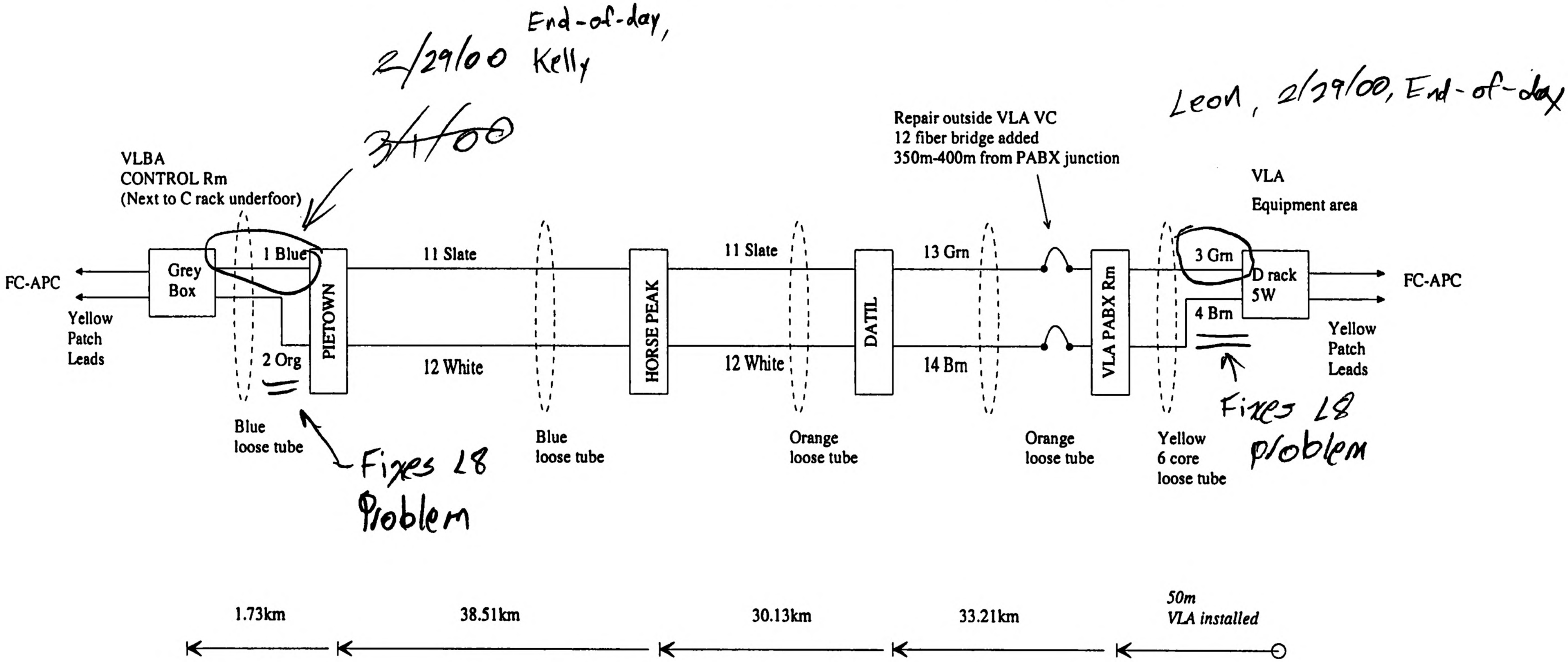
Total Loss at 1550nm = 32.4dB

Total Loss at 1310nm = 47.5dB

Actual in
25 dB

Ron Beresford 27 Aug 97

PIETOWN to VLA WESTERN NEW MEXICO TELEPHONE COMPANY FIBER



Approximate distances supplied by WNMT

ATTENUATION MEASUREMENTS

FIBER	λ = 1550nm	λ = 1310nm
Blue1 - Grn3 VLBA-VLA	22.5 dB	37.4dB
Org 2 - Brn4 VLBA-VLA	24.4dB	38.6dB

COLOR Code

1 Blue
2 Orange
3 Green
4 Brown
5 Slate
6 White
7 Red
8 Black
9 Yellow
10 Violet
11 Turquoise
12 Pink

WNMT Contact Numbers

JANET (bookings) 505-535 2242
SHERMAN YATES 505-772 9901
JR MCKINNELY (pager) 505-574 3056
JERRY McBRIDE 1-800-5350611
Hm 535 2731
JOHN STATS 505-3882546

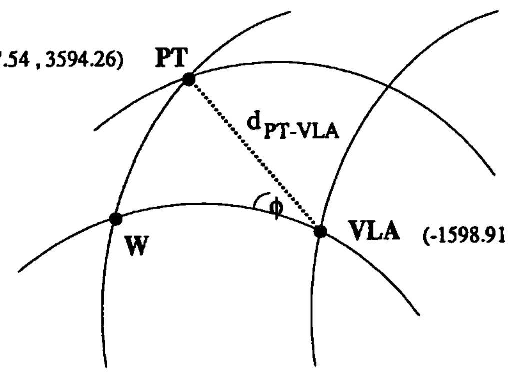
Most important phone #

rjb 17 Sept 98

FRINGE ROTATION RATE VLA/PT

VLA (centre) co-orrdinates Latitude 34° 04' 43.497" N = 34.079 °
Longtitude 107°37' 03.819" W = 107.618°

PT co-ordinates Latitude 34° 18' 03.61" N = 34.301 °
Longtitude 108°07' 07.24" W = 108.119°



In Cartesian Co-ordinates (x ,y , z)

$x = r\,\mathrm{Cos}(a)\,\mathrm{Cos}(b)$

$y = r\,\mathrm{Cos}(a)\,\mathrm{Sin}(b)$

$z = r\,\mathrm{Sin}(a)$

where a is LAT
b is LONG

r = 6378 km radius of earth

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$$

$$d_{PT\text{-}VLA} = \sqrt{39.61^2 + 27.55^2 + 20.47^2}$$

= 52.41 km

Point W is 34.079° N Lat
108.119° W Long
(-1642.85 , 5020.75 , 3573.8)

$d_{PT\text{-}W}$ **= 24.74 km**

$$\phi = \mathrm{Sin}^{-1}\left(\frac{d_{PT\text{-}W}}{d_{PT\text{-}VLA}}\right)$$

$$= \mathrm{Sin}^{-1}\left(\frac{24.74}{52.41}\right)$$

$$= 28.17^{\circ}$$

vincalc.atw

rjb 14 Jan 98

FRINGE ROTATION RATE VLA/PT

f_n = fringe rate

$$f_n = \omega_o D \, \mathrm{Cos}(\delta) \, \mathrm{Cos}(\phi) \, \mathrm{Sin}(H-h)$$

ω_o = angular rotation of earth

$= 15^\circ/\mathrm{hr}$

$$= 15 \times \frac{\Pi^c}{180 \times 3600} \ /\mathrm{sec}$$

$= 7.27 \times 10^{-5} \ {}^c/\mathrm{sec}$

Assume worst case senario

$\delta = 0^\circ$, $H - h = 90^\circ$

$$f_n = \omega_o \frac{d_{PT\text{-}VLA}}{\lambda} \mathrm{Cos}(\phi)$$

$$= \omega_o \, d_{PT\text{-}VLA} \frac{f_{sky}}{c} \mathrm{Cos}(\phi)$$

$$= 7.27 \times 10^{-5} \times 52410 \times \frac{45 \times 10^9}{3 \times 10^8} \mathrm{Cos}(28.17)$$

$= 503.8$ Hz ← Max. fringe rate ∠7 max ≈ 500 Hz

$$\text{RMS } \Phi_{rror} = \frac{\pi}{\sqrt{180}} \frac{d_{PT\text{-}VLA}}{\lambda} \mathrm{Cos}(\phi) \, H_1^2$$

$$= \frac{\pi}{\sqrt{180}} \times 52410 \times \frac{45 \times 10^9}{3 \times 10^8} \mathrm{Cos}(28.17) \, H_1^2$$

$$= 1.62 \times 10^6 \, H_1^2 \ c$$

for RMS $\Phi_{error} = 1^\circ$

$$H_1 = \sqrt{\frac{\pi}{180 \times 1.62 \times 10^6}} \ c$$

$= 1.04 \times 10^{-4}$ c

$f_{sky} = 45\mathrm{GHz}$

δ = declination

H = hour angle

D = number of wavelengths

H_1 is in radians

$$H_1 \text{ (seconds)} = \frac{H_1 \text{ (radians)}}{\omega_o}$$

$$= \frac{1.04 \times 10^{-4} \ c}{7.27 \times 10^{-5}}$$

= 1.43 secs

$$\Phi_{total} = \frac{180}{\pi} \int 2\pi f_n \, \delta t$$

$= 360 \times 503.8 \times 1.43$

$= 2.59 \times 10^5 \ {}^\circ$

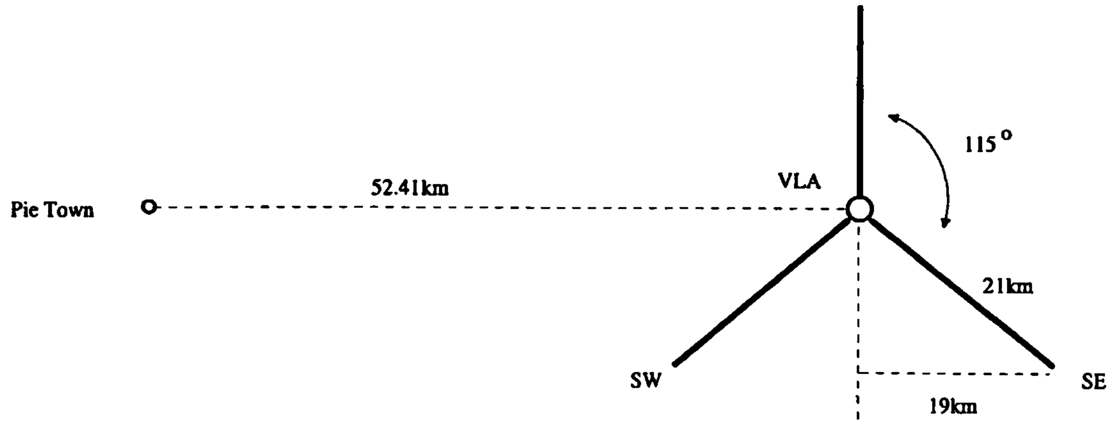
$$\text{frequency step} = \frac{f_n}{\Phi_{total}}$$

= 1.9 mHz

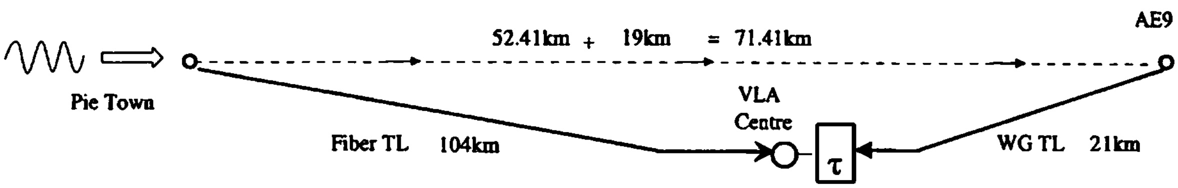
hence a 1.9mHz increment is required every 1.43 secs to maintain < 1° instrumental error

rj 14Jan 98

DELAY REQUIREMENTS



SOURCE IN WEST SKY



$$\tau_{fiber} = \tau_{radio} + \tau_{WG} + \tau$$

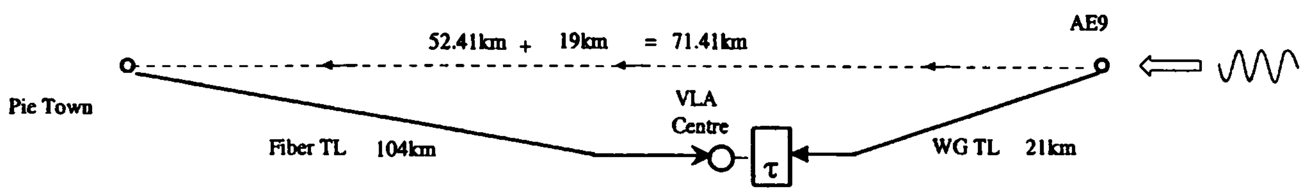
$$\frac{L_{fiber}\eta_{fiber}}{C} = \frac{L_{radio}\eta_{air}}{C} + \frac{L_{WG}\eta_{WG}}{C} + \tau$$

$$\frac{104000 \times 1.46}{3 \times 10^8} = \frac{71400 \times 1.00}{3 \times 10^8} + \frac{21000 \times 1.01}{3 \times 10^8} + \tau$$

$$506\mu S = 238\mu S + 71\mu S + \tau$$

$$\tau = 197\mu S$$

SOURCE IN EAST SKY



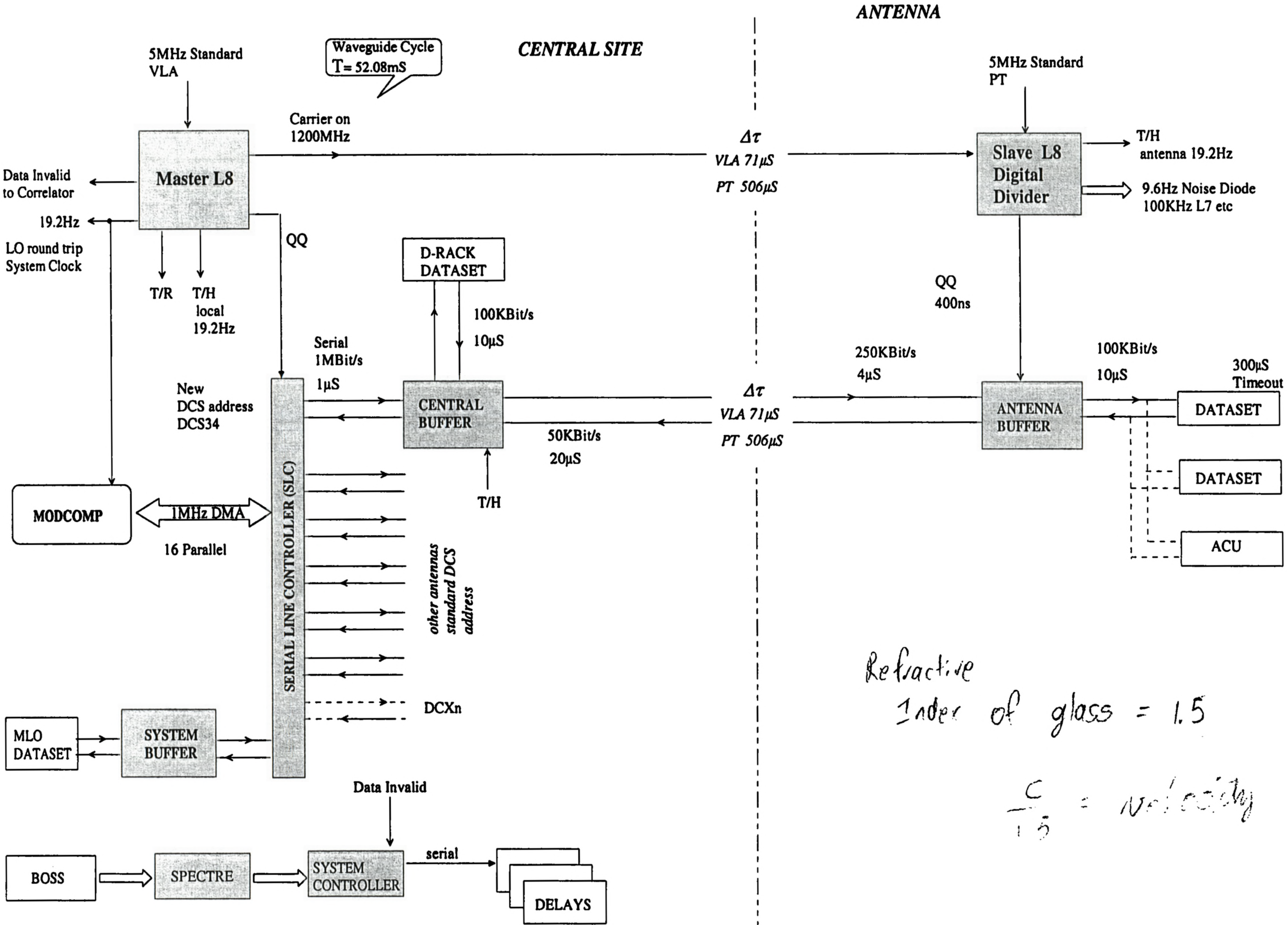
$$\tau_{radio} + \tau_{fiber} = \tau_{WG} + \tau$$

$$238\mu S + 506\mu S = 71\mu S + \tau$$

$$\tau = 675\mu S$$

hence required delay range	$197\mu S < \tau < 675\mu S$

PT - VLA Monitor Control System (MCS) signal flow



Refractive
Index of glass = 1.5

$\frac{c}{1.5}$ = velocity

Ron Beresford 9 Feb98

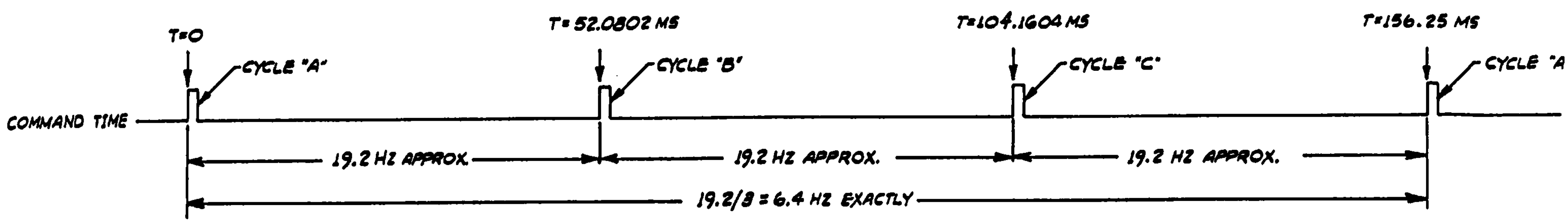
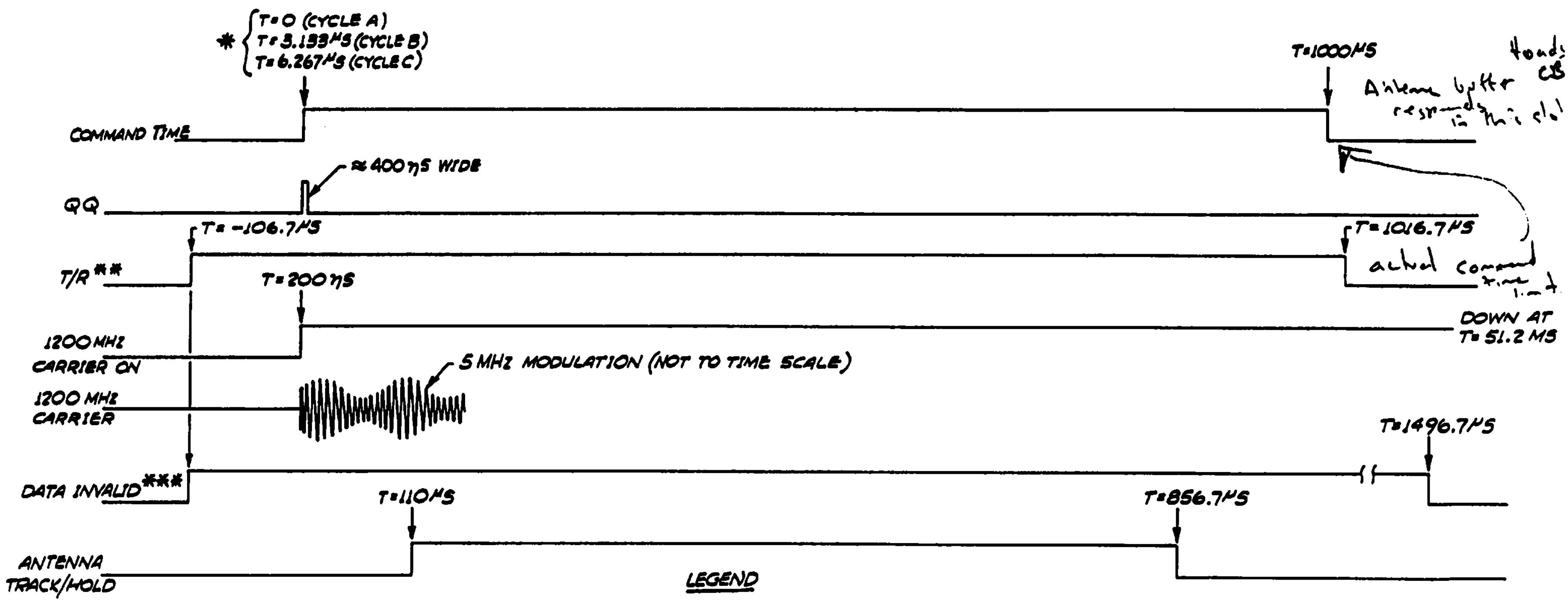


FIG. 2-A

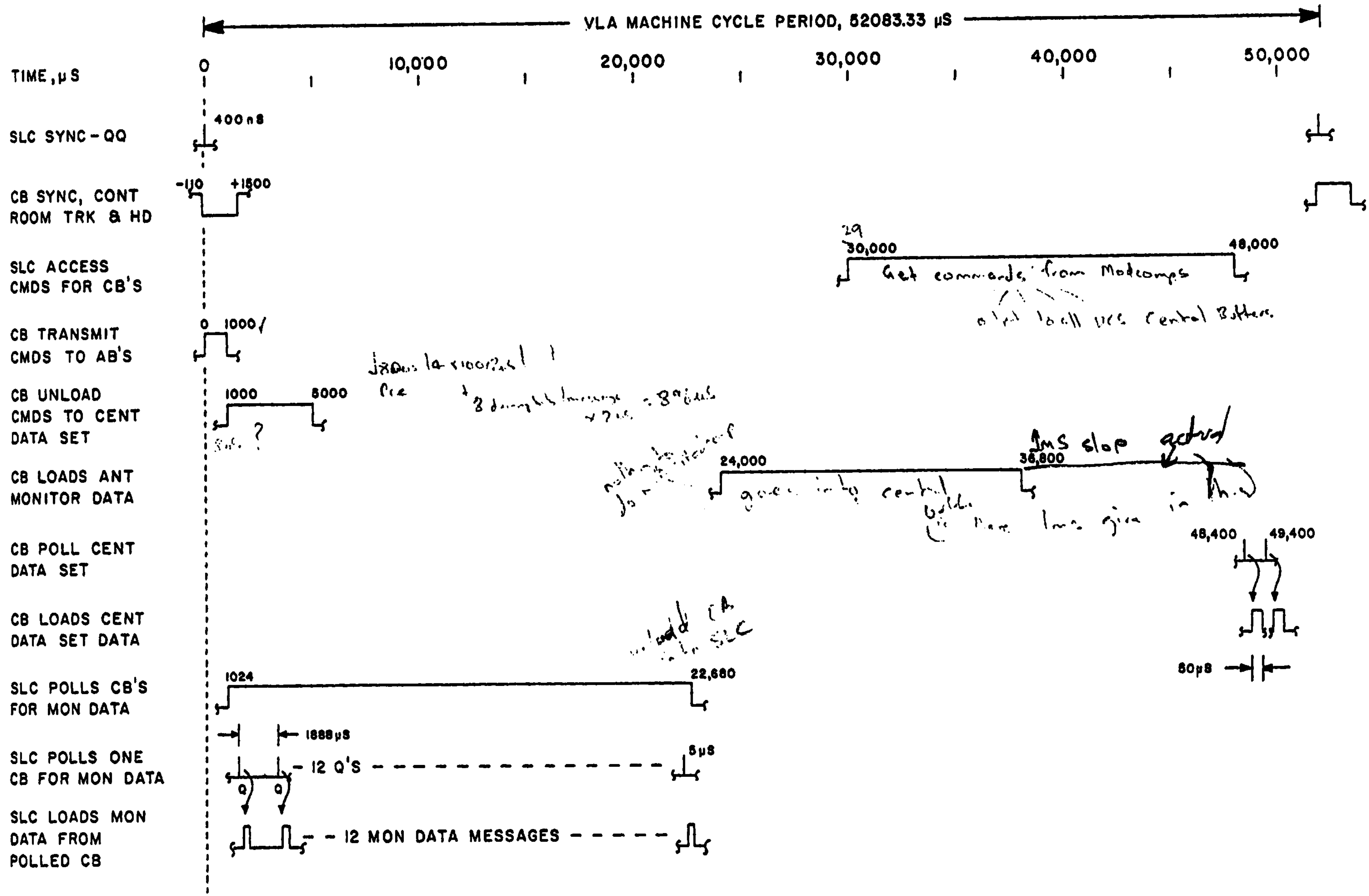


LEGEND

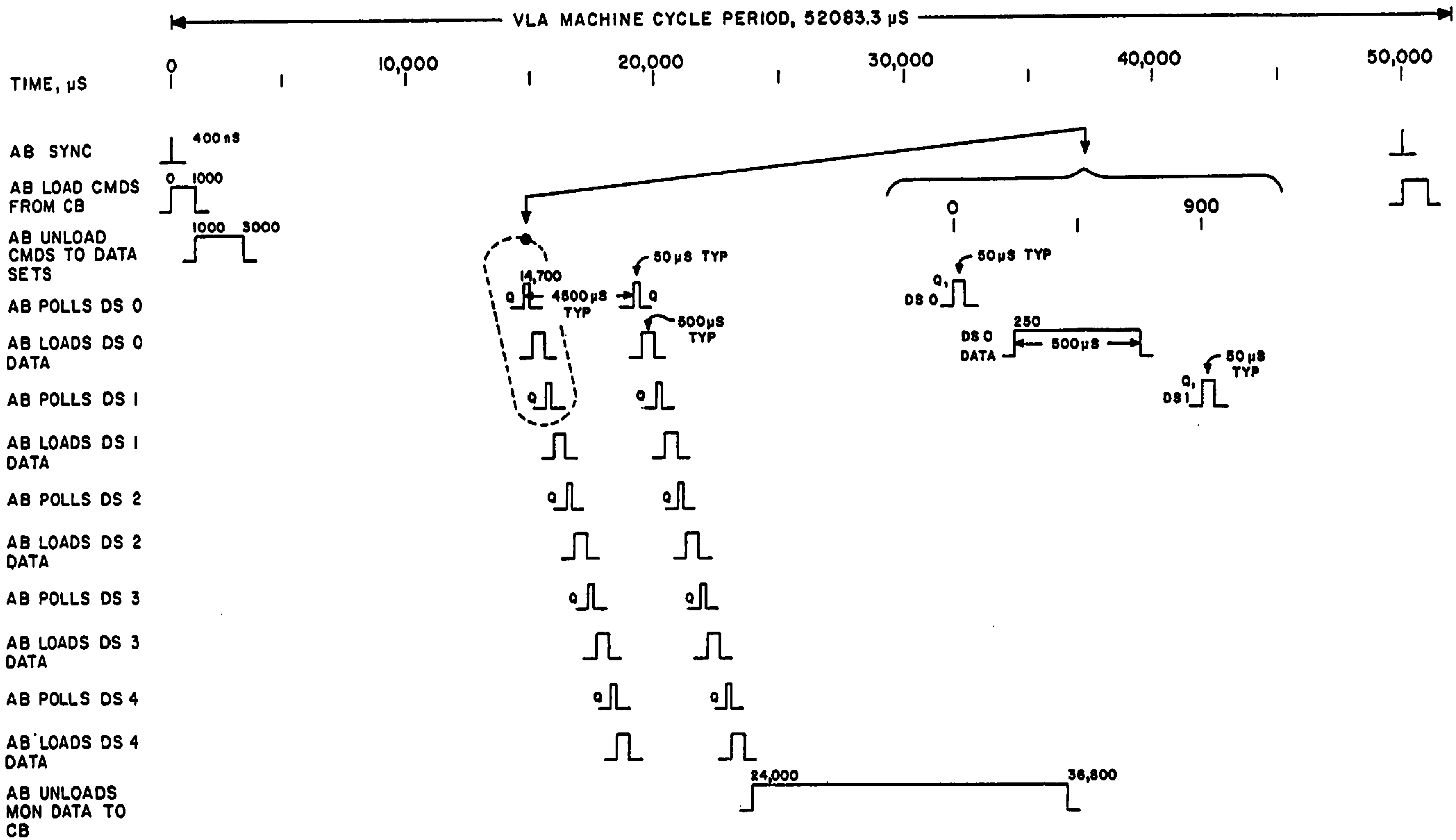
*- ALL OTHER TIMES IN FIG. 2-B CALCULATED AS IF COMMAND TIME STARTED AT T=0 EXACTLY.

**- INVERTED AT ANTENNA

***- ALSO LOCAL TRACK/HOLD



TIMING DIAGRAM 1: CENTRAL TIMING OPERATIONS



TIMING DIAGRAM 2: ANTENNA TIMING OPERATIONS

2. System Design

2.1 Overview

The purpose of the PT link is to transport amplitude and phase stable 50MHz bandwidths signals ,a total of 200MHz bandwidth from the sky frequencies common to both VLA and VLBA sites.
As the VLA has limited correlator capacity (nominally 27 VLA antennas) when observing PT/VLA mode antenna DCS2 ,the donor antenna ,is removed from the correlator at the DCS2 D rack and the D rack subsequently connected to the PT antenna via the link. This can be an automated process.

Where possible the PT link has been designed to be naturally compatible with the VLA in both hardware and software with significant reuse of both .

The sky frequency at PT is firstly converted to the nominal 500-1000MHz IF band for both LCP and RCP in the existing VLBA system. These IF's are then converted to the nominal VLA waveguide channels of A 1325MHz ,C 1575MHz and B 1425MHz ,D 1675MHz by using IF converter modules T201A,B with local oscillators L6 selectable in either the VHF range of 339.9MHz to 689.9MHz or the UHF range of 2260.1 to 2610.1MHz . The use of UHF or VHF is determined by the SSB sense required to maintain compatibility and flexibility with the VLA system.

The local oscillators fringe rotated via L7 modules and are both phase coherent and phase continuous to the PT rack LO reference chain L1,L2,L3 which are coherent to the PT maser station reference.
The VLA waveguide channels output from the T201 modules are individually automatic level controlled to -7dBm in modified F4 ALC / Synchronous demodulator modules. This provides required signal dynamic range under a variety of conditions.

The A,B,C,D and a sample of a 1200MHz signal multiplied from the PT Maser are combined to provide drive for the analog fiber optic transmitter T202 in a direct detection intensity modulated scheme. A high power 50mW DFB laser operating precisely at 1554nm provides a CW optical source which is externally modulated by a MZ optical modulator.

The recovered photodiode signal at the VLA is effectively switched into the VLA T3 baseband converter module input in preference to VLA antenna DCS2. In addition a one way phase reckoning of the 1200MHz reference tone from the PT Maser is compared with a 1200MHz tone as generated from the VLA MLO system. This is done with the existing D rack L14 LO filter and L11 LO measurement module in conjunction with the D rack switch plate.

The installed fiber base is dated high dispersion 18ps/nm/km fiber with minimum optical loss at 1550nm band. Any aberation in the optical wavelength of the analog DFB will translate in large ,unacceptable changes in RF phase. The 1200MHz reckoning has both transmission line artifacts and site to site maser frequency differential are buried in the measurement.

In order to provide required monitoring and control information of the PT rack and most importantly synchronization of the PT LO fringe rotation and noise diode switching with the VLA waveguide cycle a bidirectional high bit rate digital multiplexer using highly integrated HP chipsets and a directly modulated on/off keyed digital fiber optic link is used. Each direction has a separate optical wavelength.

Provision has also been made to multiplex onto the digital chipset a low bit rate 'B' channel tie line,perhaps replacing the existing public switched network connection as an operational enhancement if desired.

Including the analog path there are a total of 3 unique optical wavelengths that are multiplexed using WDM thin film interference filter techniques onto a single singlemode fiber core in a mix of analog ,digital and bidirectional function.

1.3 Draft Specification

VLA to PIE TOWN LINK DRAFT SPECIFICATION

Ron Beresford 20 Feb 98

General

For purposes of this specification the word "link" is used to refer to any RF conversion subsystem , any Local Oscillators of the RF conversion system ,any Fiber Opto Electronics , any data communications hardware or any combination there of located between the PT VLBA IF Cable Termination Panel and the VLA correlator inputs.

The PT/VLA link will facilitate connection of the PT VLBA antenna to the VLA . The PT antenna will replace one of the VLA antenna inputs to the VLA correlator.
As a substitute "27^{th} " antenna and "outrigger" to the VLA "Y" the addition of PT to the VLA will predominately enhance spatial resolution and observing capabilities of the VLA rather than that of the VLBA. The PT - VLA link will be used predominately by VLA observing schedules.

SPECIFICATION

The link shall :-

1. Maintain where possible , familiarity with existing VLA architecture.
2. Maximize use of existing , spare , VLA module hardware where spare modules are available.
3. Minimize any internal modifications required to spare modules where spare modules are utilized.
4. Maximize re-use of VLA software routines/subroutines where appropriate.
5. Provide fully compatible sky coverage at all observing frequencies common to the VLA and PT VLBA receivers . (Upper limit is 45GHz).
6. Not compromise continuum or spectral line observing modes of the VLA in any way.
7. Provide a high integrity moderate bandwidth (64kb/s to 10Mb/s) WAN connection between sites unreliant on PSTN performance for the periods of observation involving PT in the VLA.
8. Endeavor to work over a single fiber core of the Western New Mexico telephone company supplied cable.
9. Utilize fiber optic electronic techniques , commensurate with the latest contemporary and commercially accepted design practices.
10. Be designed in a direction that could be applied to future upgrades of the VLA , and other projects requiring high bandwidth remoting of antennas with analog and/or digital requirements.
11. Allow future provision for site to site LO reference signals to be transmitted , bidirectionally between sites. This may be a frequency offset round trip phase measurement system or another innovative method.
12. Provide transmission of all 4 Intermediate Frequency outputs (2 Frequency ,2 Polarizations)

13. Provide a transmission 3dB bandwidth not less than 50MHz per IF and be readily expandable to 70MHz per IF.

14. Contribute less than 0.5K or 1% (which ever is the lower) to the total system temperature T_{sys} at any given observing band.

15. Permit T_{sys} calibration using FE noise diode switching in synchrony and phase with the VLA waveguide cycle rate of 9.6Hz.

16. Provide for real time synchronous operation of PT events with the VLA 52ms waveguide cycle and confine all set-up processes to the nominal Data Invalid Interval as defined by the VLA correlator. The configuration of "new" scans and processes involving the PT Tracking /servo control and PT specific monitor /control are exempt from this requirement.

17. Contribute no more than 1 ° rms in phase drift ,as would be seen in baseline visibilities ,at any given observing frequency over any 30min period.

18. Where LO's are required in the conversion to base-band , utilize phase coherent LO's. The toggling between any two different observing frequencies will be phase coherent and between any two same frequencies will be phase continuous. In addition ,phase coherence will be recoverable after power down /up cycles.

19. Permit normal dual frequency ,2 x sub-array operation of the VLA , with PT as a member of one sub-array.

20. Have a total 4 x IF channel Spur Free Dynamic Range (SFDR) minimum of 85dB $Hz^{(2/3)}$ or 30dB for 200MHz BW.

21. Operate each IF ,at 50MHz BW , with a signal to noise ratio SNR exceeding 20dB.

22. Provide for Automatic Level Control ALC on a long time constant to maintain ample link average modulation depth and a uS time constant spike suppression of sporadic unwanted interference and RFI in the IF pass-bands.

23. Provide ,primarily as a diagnostic feature , a method for monitoring the IF power levels modulating the link immediately prior to opto-electronic transmitters.

24. Suppress any single unwanted LO or unwanted inter-modulation products a minimum 5dB below the IF channel noise floor.

25. Have a BER of better than 1×10^{-7} at all VLA data communication bit rates .(The current VLA BER for the MCS is 3×10^{-7}). For site to site WAN the BER shall be better than 1×10^{-9} at the chosen bit rate.

26. As per ITU standards provide a " hardwired" laser safety shutdown feedback control where laser optical power capable of being launched from any bare fiber within the system can exceed 50mw.

27. Allow a coarse delay range available for the delay subsystem of the correlator in the range of 197uS to 675uS in 10nS steps .Fine delay shifting will remain unchanged at 625ps steps.

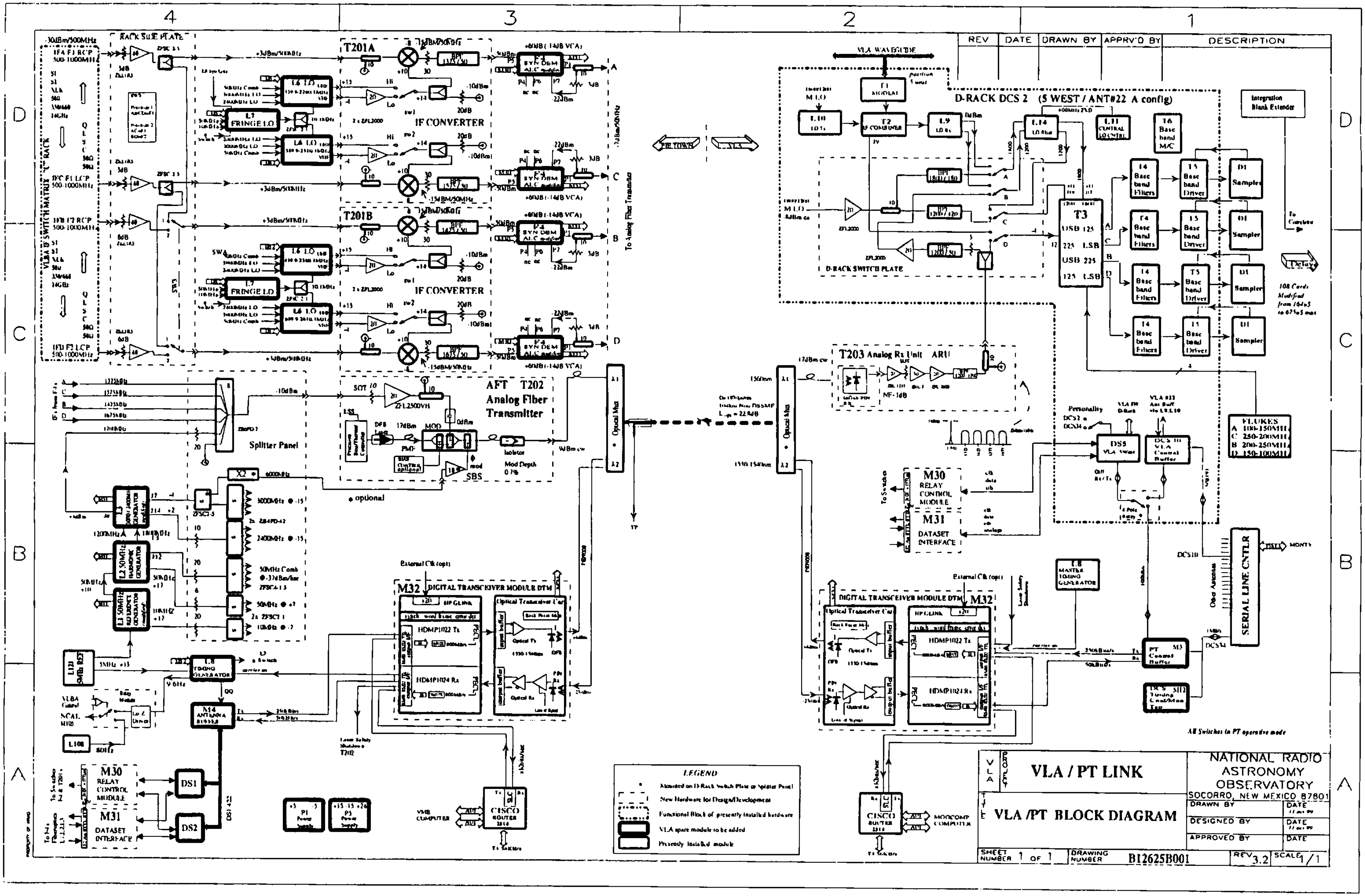
28. Provide a fringe frequency rate of up to +/-500Hz and be programmable in increments no larger than 2mHz every 1.5 seconds. The start phase must be programmable in 0.72 ° steps or less.

29. Allow the conversion to baseband facilitate independent SSB selection of F1 and F2 IF's such that any combination of common VLA and PT observing frequencies will always have the correct SSB sense presented to the samplers (RCP and LCP's will always remain opposite SSB sense)

30. Be sufficiently configurable with minimal complexity to any one of the 27 available VLA correlator inputs. (5 West initially)

31. Work unconditionally over time and temperature.

32. Be constructed to budget and on time.


VLA / PT LINK
VLA /PT BLOCK DIAGRAM
NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO 87801
DRAWING NUMBER B12625B001
REV 3.2
SCALE 1/1
SHEET NUMBER 1 OF 1
REV
DATE
DRAWN BY
APPRV'D BY
DESCRIPTION
DRAWN BY
DESIGNED BY
APPROVED BY
RACK SIDE PLATE
T201A
T201B
IF CONVERTER
FRINGE LO
AFT T202
Analog Fiber
Transmitter
Splitter Panel
T203 Analog Rx Unit ARU
D-RACK DCS 2 (5 WEST / ANT#22 A config)
D-RACK SWITCH PLATE
VLA WAVEGUIDE
Sampler
FLUKES
A 100-150MHz
C 250-200MHz
B 200-250MHz
D 150-100MHz
SERIAL LINE CNTLR
M30
RELAY CONTROL MODULE
M31
DATASET INTERFACE
M32
DIGITAL TRANSCEIVER MODULE DTM
HDMP1022 Tx
HDMP1024 Rx
CISCO ROUTER
DS1
DS2
LEGEND
Mounted on D-Rack Switch Plate or Splitter Panel
New Hardware for Design/Development
Functional Block of presently installed hardware
VLA spare module to be added
Presently installed module
All Switches in PT operative mode
VLBA IF SWITCH MATRIX "L" RACK
To Analog Fiber Transmitter
Optical Mux
FR TOWN
VLA

PT FREQUENCY CONVERSION

PT FREQUENCY CONVERSION
T202 A,B , F4

The installed receivers and the RF conversion chains of the PT VLBA antenna is different to that of a typical VLA antenna.
The PT antenna has bands from 74MHz P-band to 86GHz W-band. The VLA can have P-Band thru to Q-band only as equiped. Significantly ,there are other major differences between the two systems.

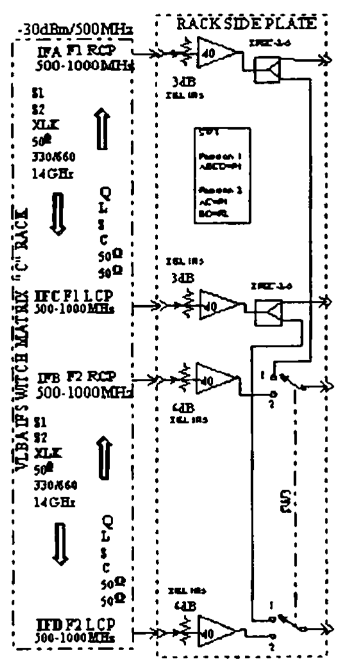
VLBA antennas have no real time fringing as this is done during the off line VLBA correlation process. The VLA antennas have fringe rotation in real time at the antennas via L7 modules.

Antenna position control is via the Modcomp computers driven by operator console at the VLA while at PT the antenna position control is via the VLBA control centre at the AOC and landline B channel access to the VME controller at PT.

The VLBA conversion system has LO's that tune in steps of +/-200 or +/-300MHz in converting down to the 500 - 1000MHz IF slot. The VLA conversion system moves in steps of 50MHz +/-10.1MHz fringe rotated.

The VLBA backend was intended to process as SSB conversion relatively narrowband 16MHz IF BW. The VLA processes four SSB relatively wideband 50MHz IF BW's.

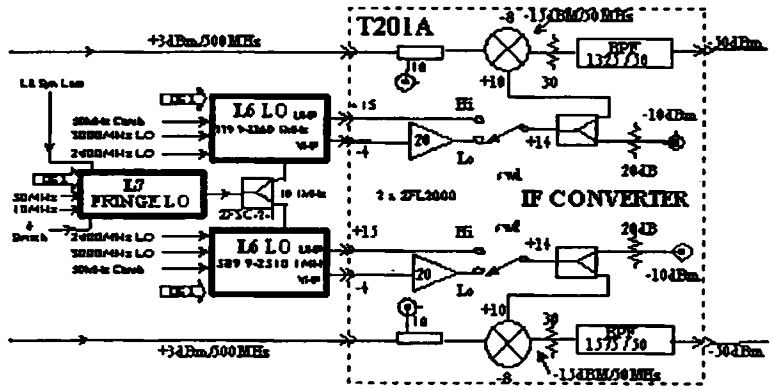
VLBA IF output



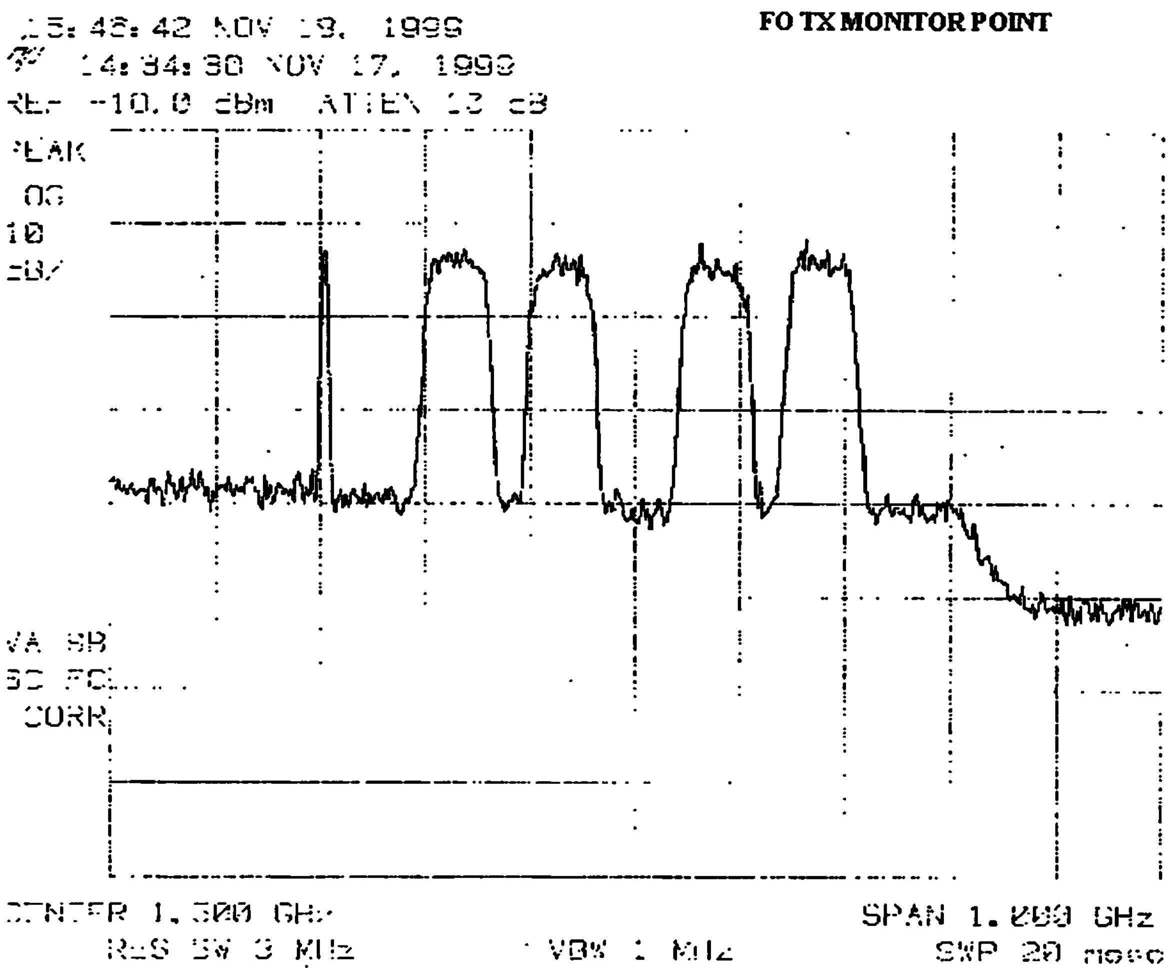
The VLBA antenna furnishes a wideband of sky frequencies (F_{sky}) downconverted to an IF of 500-1000MHz for each of the left and right circular polarizations. These IF's nominally appear at either the A&C channels respecively or the B&D channel respectively as determined by the VLBA matrix switch

The VLA (A,B,C,D) 50MHz bandpass response is determined largely by the 8 pole K&L bandpass filters.

For 70MHz channel operation slightly less selective 6 pole RLC filters are available ,although these filters are physically shorter and will require a new semi rigid cable.



FO TX MONITOR POINT



F4 1325MHz Voltage Controlled Attenuator Characteristics

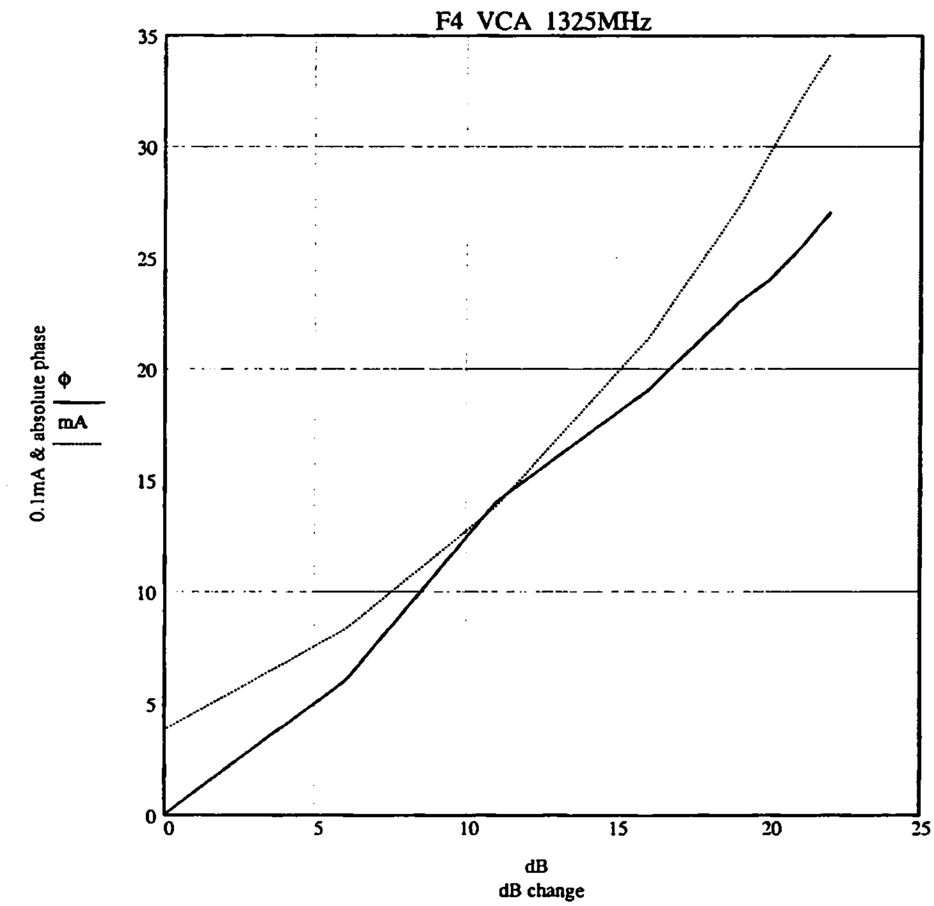
$$V := \begin{bmatrix} .38 & -23 & -20 \\ .83 & -17 & -14 \\ 1.38 & -9 & -9 \\ 2.13 & -4 & -4 \\ 2.73 & 0 & -1 \\ 2.97 & 1 & 0 \\ 3.21 & 2.4 & 1 \\ 3.42 & 4 & 2 \end{bmatrix}$$

$i := 0, 1 .. \text{rows}(V) - 1$

$mA_i := V_{i,0} \cdot 10$

$n := 0, 1 .. \text{rows}(V) - 1 \qquad V_{0,1} = -23$

$\phi_n := V_{n,1} - V_{0,1} \qquad dB_n := V_{n,2} - V_{0,2}$



F4 1425MHz Voltage Controlled Attenuator Characteristics

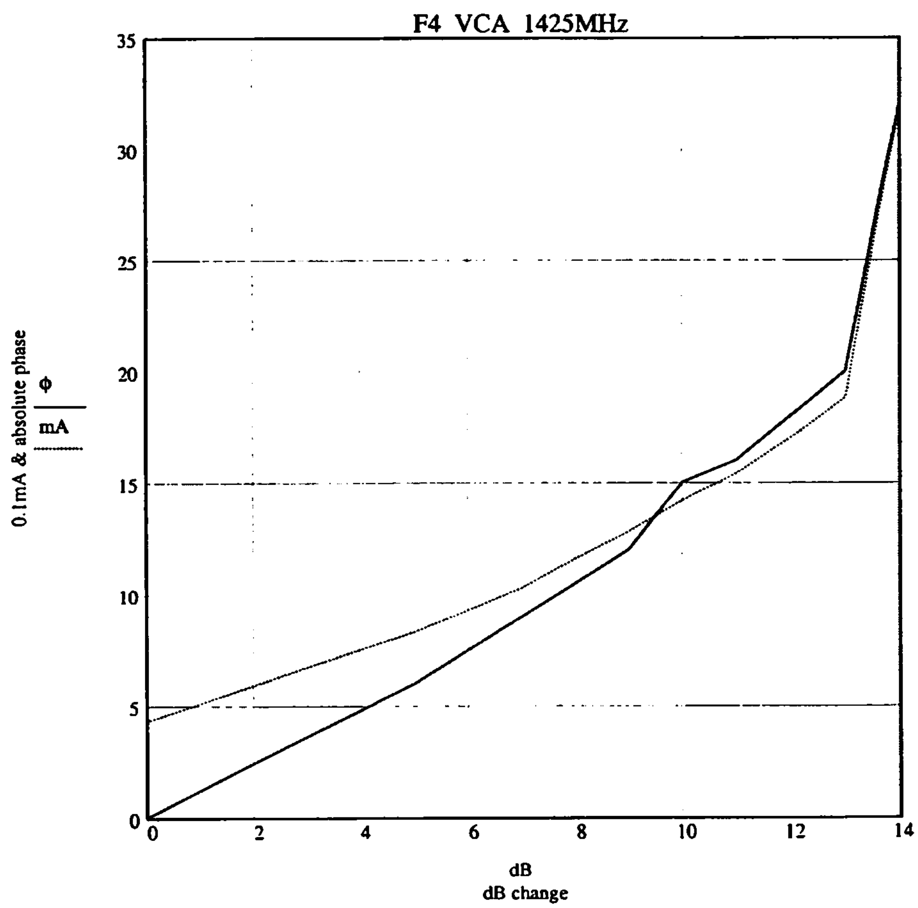
$$V := \begin{bmatrix} 0.43 & -6 & -8 \\ 0.83 & 0 & -3 \\ .93 & 1.5 & -2 \\ 1.03 & 3 & -1 \\ 1.16 & 4.5 & 0 \\ 1.28 & 6 & 1 \\ 1.42 & 9 & 2 \\ 1.54 & 10 & 3 \\ 1.7 & 12 & 4 \\ 1.88 & 14 & 5 \\ 3.19 & 26 & 6 \end{bmatrix}$$

$i := 0, 1 .. \text{rows}(V) - 1$

$mA_i := V_{i,0} \cdot 10$

$n := 0, 1 .. \text{rows}(V) - 1$ $\quad V_{0,1} = -6$

$\phi_n := V_{n,1} - V_{0,1}$ $\quad dB_n := V_{n,2} - V_{0,2}$



F4 1575MHz Voltage Controlled Attenuator Characteristics

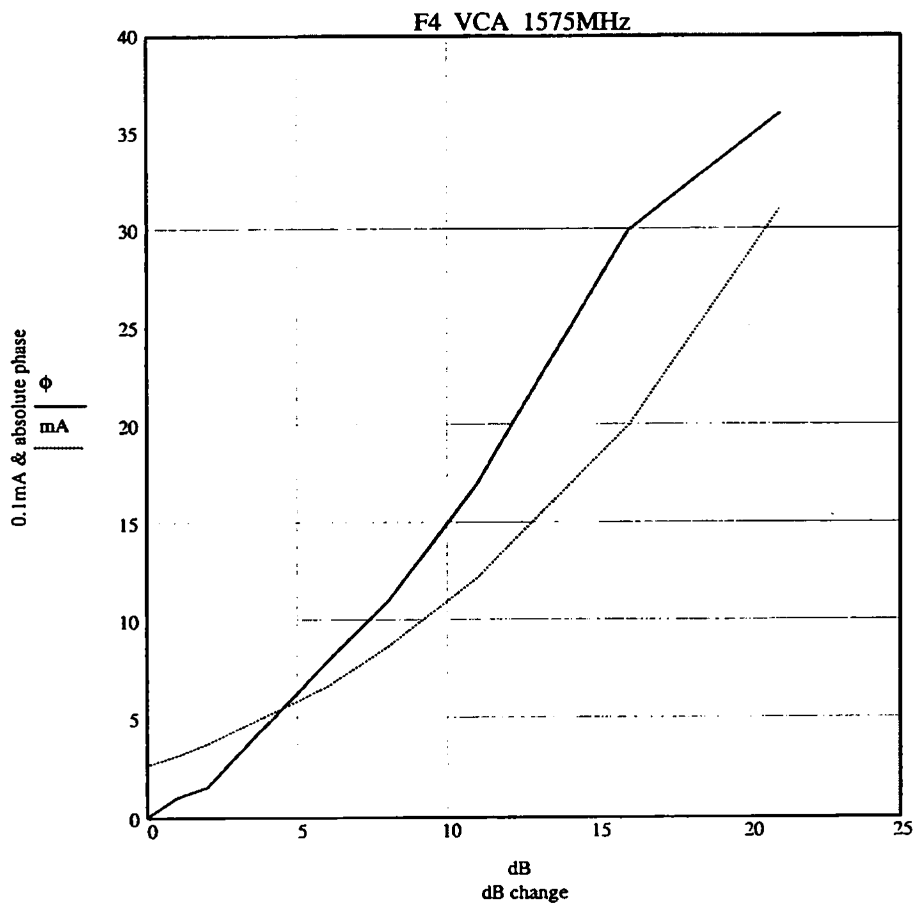
$$V := \begin{bmatrix} 0.26 & 0 & -6 \\ .31 & 1 & -5 \\ .37 & 1.5 & -4 \\ .67 & 8 & 0 \\ .87 & 11 & 2 \\ 1.22 & 17 & 5 \\ 2 & 30 & 10 \\ 3.11 & 36 & 15 \end{bmatrix}$$

$i := 0, 1 .. \text{rows}(V) - 1$

$mA_i := V_{i,0} \cdot 10$

$n := 0, 1 .. \text{rows}(V) - 1$ $\qquad V_{0,1} = 0$

$\phi_n := V_{n,1} - V_{0,1}$ $\qquad dB_n := V_{n,2} - V_{0,2}$



F4 1675MHz Voltage Controlled Attenuator Characteristics

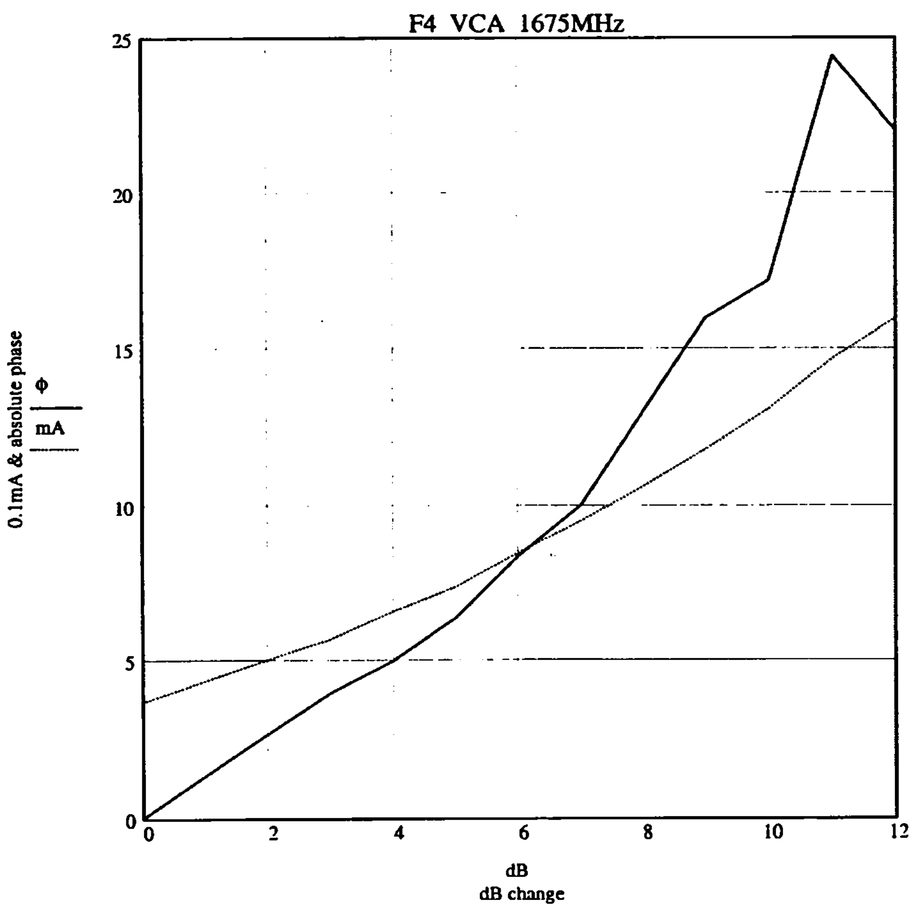
$$V := \begin{bmatrix} 0.37 & -22 & -16 \\ .57 & -18 & -13 \\ .66 & -17 & -12 \\ .74 & -15.6 & -11 \\ 0.85 & -13.6 & -10 \\ 0.95 & -12 & -9 \\ 1.06 & -9 & -8 \\ 1.18 & -6 & -7 \\ 1.31 & -4.8 & -6 \\ 1.47 & 2.4 & -5 \\ 1.6 & 0 & -4 \end{bmatrix}$$

$i := 0, 1 .. \text{rows}(V) - 1$

$mA_i := V_{i,0} \cdot 10$

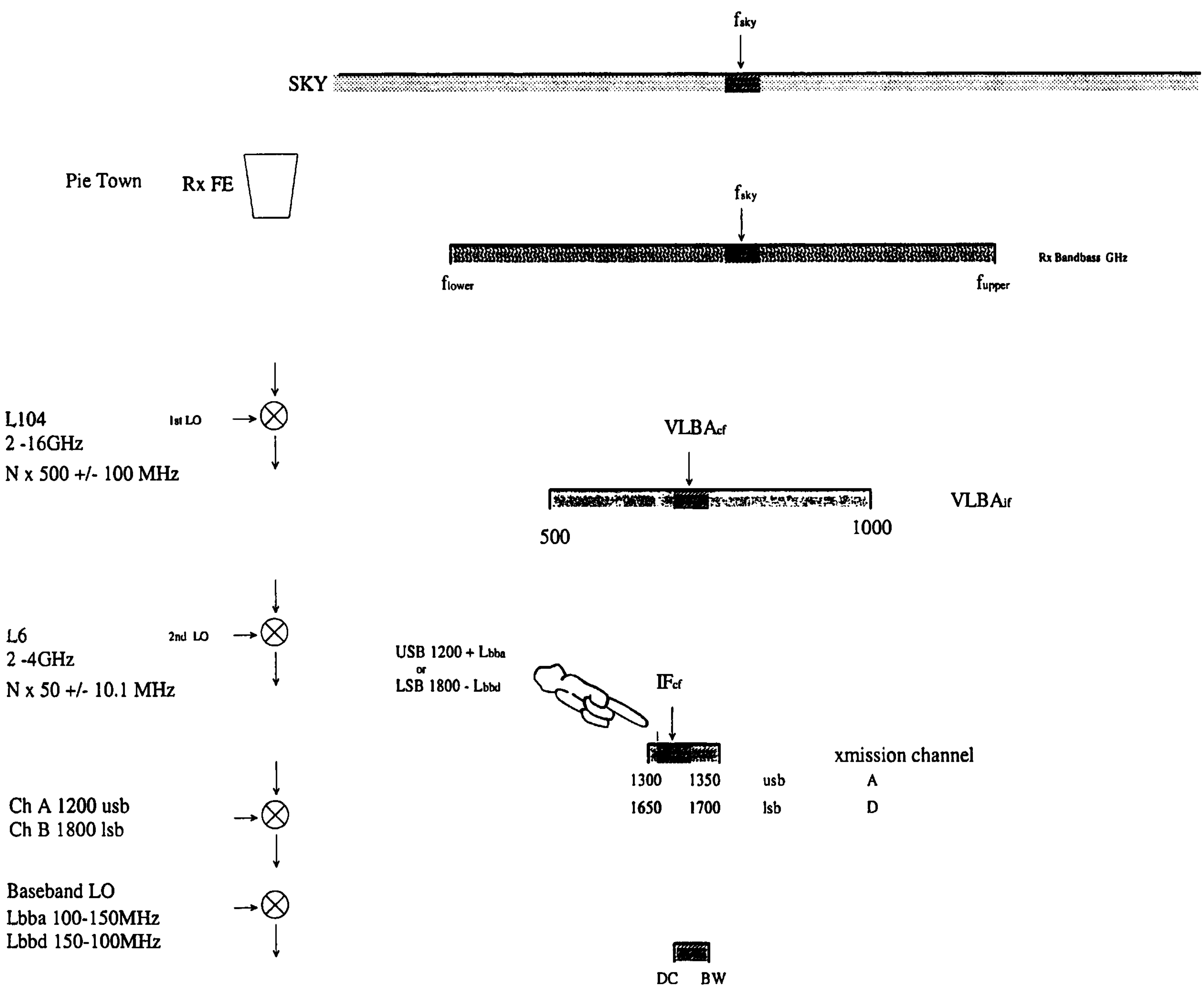
$n := 0, 1 .. \text{rows}(V) - 1$ $\quad V_{0,1} = -22$

$\phi_n := V_{n,1} - V_{0,1}$ ← -22 $\quad dB_n := V_{n,2} - V_{0,2}$ ← -16



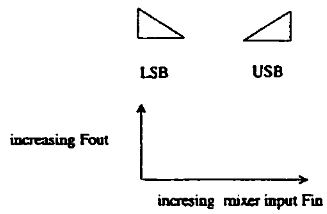
VLA -- PT link FREQUENCY CONVERSION COMPATIBILITY

Ron Beresford 1 Dec 97

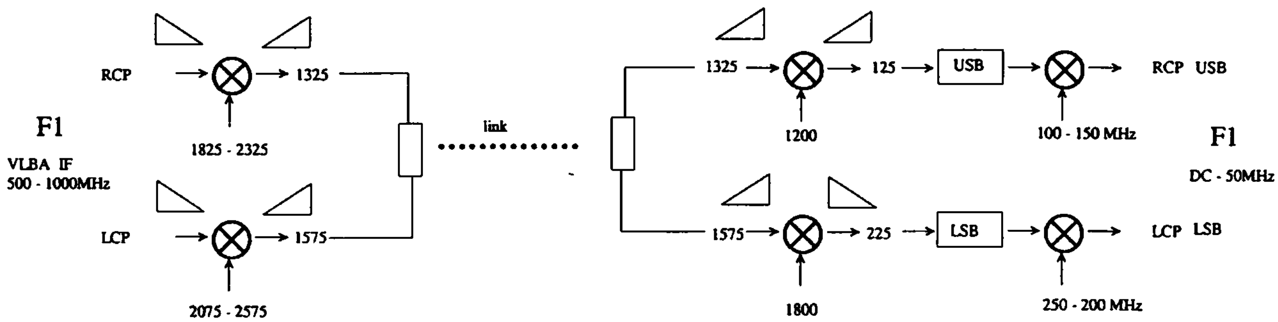


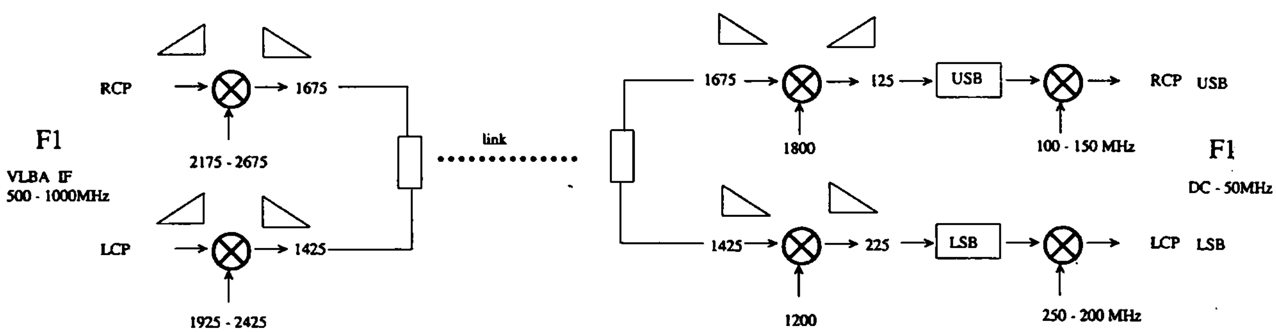
SSB DIA.drw

BASEBAND CONVERSION OVERVIEW



NB. all Figures in MHz

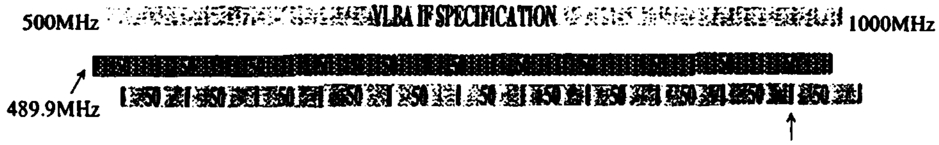




Ron Beresford 20 Nov 97

L6 L7 BASED VLBA CONVERSION SCHEME

Ron Beresford 1Dec97



L6 LO
Determined
50MHz start band
using N50 - 10.1MHz

L6 LO
Determined
50MHz start band
using N50 + 10.1MHz

RCP

VLBAif A 500 - 1000MHz ⇒ ⊗ ⇒ VLA IF CHA 1300MHz

489.9 - 1010.1

N50± 10.1± Δ

F1

Low Side LO 810.1 - 339.9 N = 16....7 (825-325) → (14.9, -14.9)
High Side LO 1789.9 - 2260.1 N = 36....45 (1825-2325) → (35.1, 64.9)

LCP

VLBAif C 500 - 1000MHz ⇒ ⊗ ⇒ VLA IF CHC 1550MHz

489.9 - 1010.1

N50± 10.1± Δ

Low Side LO 1060.1 - 589.9 N = 21....12 (1075-575) → (14.9, -14.9)
High Side LO 2039.9 - 2510.1 N = 40....50 (2075-2575) → (35.1, 64.9)

RCP

VLBAif B 500 - 1000MHz ⇒ ⊗ ⇒ VLA IF CHB 1400MHz

489.9 - 1010.1

N50± 10.1± Δ

F2

Low Side LO 910.1 - 439.9 N = 45....9 (925-425) → (14.9, -14.9)
High Side LO 1889.9 - 2360.1 N = 36....47 (1925-2425) → (35.1, 64.9)

LCP

VLBAif D 500 - 1000MHz ⇒ ⊗ ⇒ VLA IF CHD 1650MHz

489.9 - 1010.1

N50± 10.1± Δ

Low Side LO 1160.1 - 689.9 N = 23....14 (1175-675) → (14.9, -14.9)
High Side LO 2139.9 - 2610.1 N = 43....52 (2175-2675) → (35.1, 64.9)

CHA&Dcalc.drw

Ron Beresford 1Dec 97

CHANNEL A and D EXPRESSIONS

CHA VLBA$_{if}$ increasing with increasing F_{sky}

$F_{sky} - L104 = VLBA_{ifcf}$

$VLBA_{ifcf} - L6 = IF_{cf}$

$IF_{cf} = 1200 + L_{bba} + bw/2$

$F_{sky} - L104 = IF_{cf} + L6$

$= 1200 + L_{bba} + bw/2 + L6$

$$\mathbf{F_{sky} = L104 + L6 + 1200 + L_{bba} + bw/2}$$

m500 +/- 100

n50 +/- 10.1

p2 Hz

CHD VLBA$_{if}$ increasing with increasing F_{sky}

$F_{sky} - L104 = VLBA_{ifcf}$

$L6 - VLBA_{ifcf} = IF_{cf}$

$IF_{cf} = 1800 - L_{bbd} + bw/2$

$F_{sky} - L104 = L6 - IF_{cf}$

$= L6 - 1800 + L_{bbd} - bw/2$

$$\mathbf{F_{sky} = L104 + L6 - 1800 + L_{bbd} - bw/2}$$

m500 +/- 100

n50 +/- 10.1

p2 Hz

CHA VLBA$_{if}$ decreasing with increasing F_{sky}

$L104 - F_{sky} = VLBA_{ifcf}$

$L6 - VLBA_{ifcf} = IF_{cf}$

$IF_{cf} = 1200 + L_{bba} + bw/2$

$L104 - F_{sky} = L6 - IF_{cf}$

$= L6 - (1200 + L_{bba} + bw/2)$

$$\mathbf{F_{sky} = L104 - L6 + 1200 + L_{bba} + bw/2}$$

m500 +/- 100

n50 +/- 10.1

p2 Hz

CHD VLBA$_{if}$ decreasing with increasing F_{sky}

$L104 - F_{sky} = VLBA_{ifcf}$

$L6 - VLBA_{ifcf} = IF_{cf}$

$IF_{cf} = 1800 - L_{bbd} + bw/2$

$L104 - F_{sky} = L6 - IF_{cf}$

$= L6 - (1800 - L_{bbd} + bw/2)$

$$\mathbf{F_{sky} = L104 - L6 - 1800 + L_{bbd} - bw/2}$$

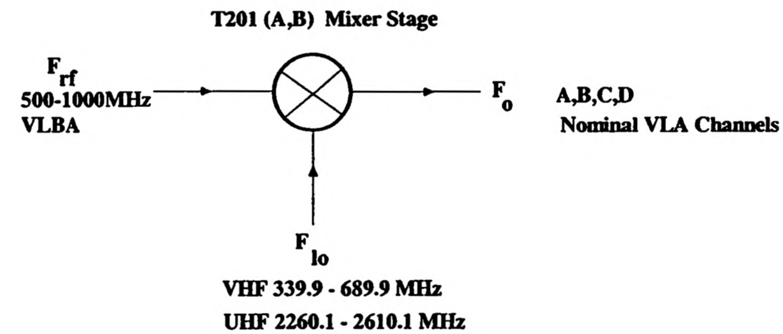
m500 +/- 100

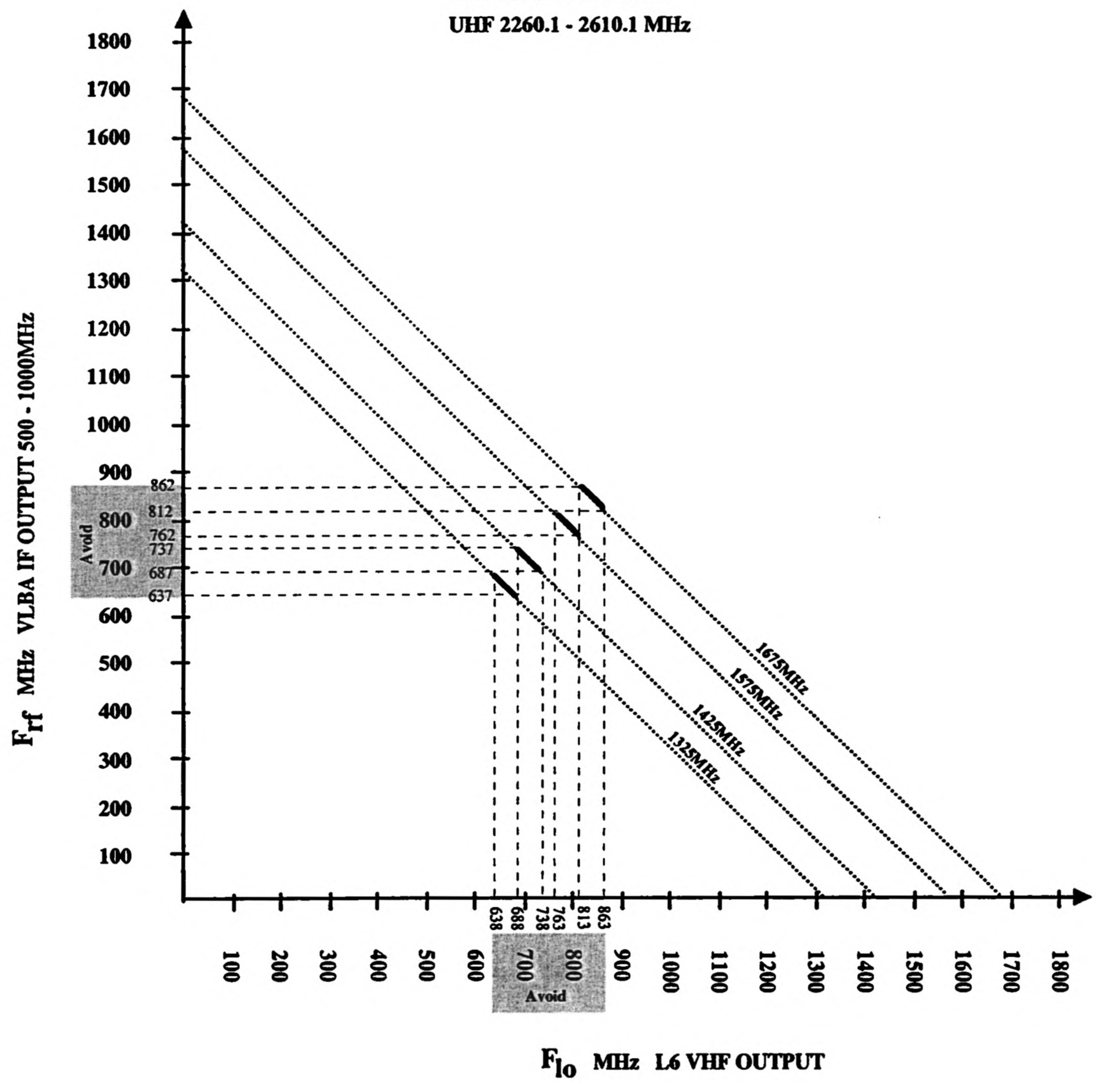
n50 +/- 10.1

p2 Hz

T201Harmics.arw

T201 CONVERTER HARMONIC LIMITS





F_o MHz	F_{lo} fundamental of 2nd Harmonic	F_{lo} fundamental of 3rd Harmonic
A 1325	638 - 663 - 688	442
B 1425	688 - 713 - 738	475
C 1575	763 - 788- 813	525
D 1675	813 - 838 - 863	558

NB VLA IF's move in pairs A,C C= A + 250MHz $F_{loC} = F_{loA} + 250MHz$

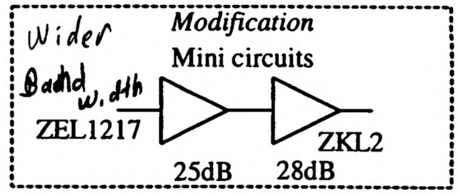
B,D D= B + 250MHz $F_{loD} = F_{loB} + 250MHz$

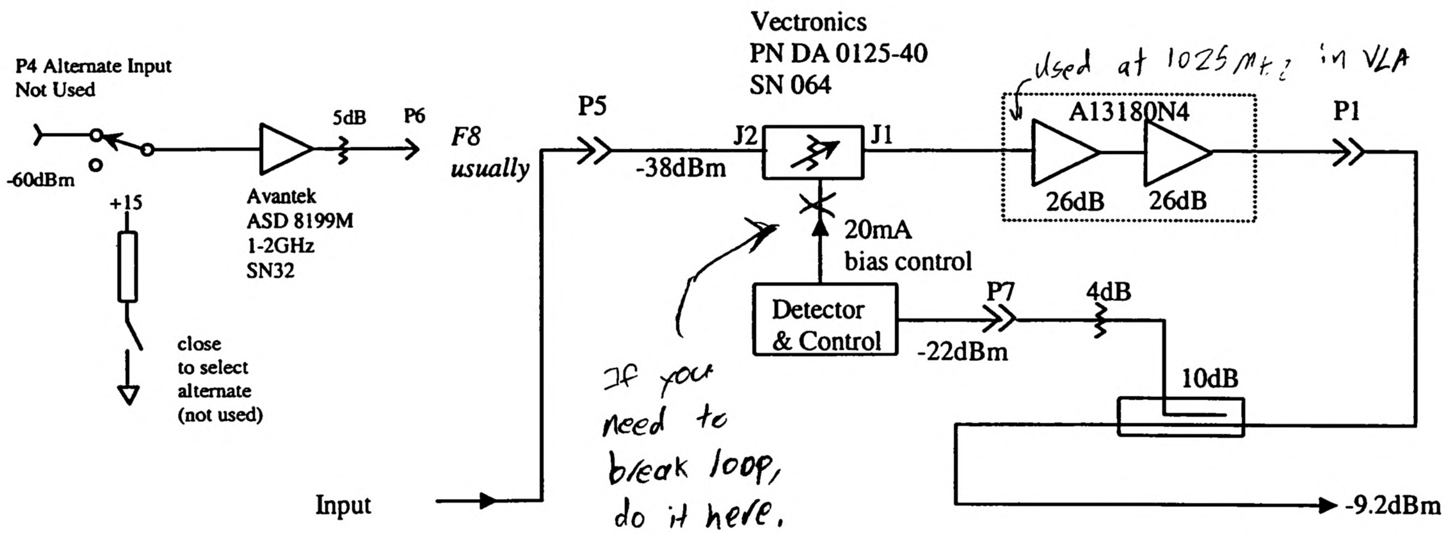
rjb 30 sept 99

f4levels.drw

F4 FREQUENCY CONVERTER /ALC UNIT

example SNC544





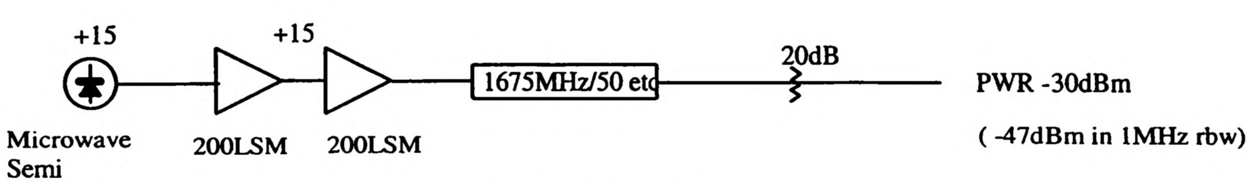
Includes spike

Measurements using white noise test source.

P4 Input Pwr dBm add 22dB for P5 level	Front Panel Meter	P1 Output Pwr dBm	VCA control current mA
-30	>100	-7.8	10.4
-40	>100	-9.2	5.3
-50	60	-10	2.6
-60	32	-9.9	1.0
-70	15	-9.9	0.26
-80	5	-7.8	0
-90	<0	-8.5	0

Best Operating

Low Gain LED 20dB Hysteresis



NOISE SOURCE

rjb 28 sept 99

WHY IT WORKS .... CONVERSION COMPATIBILITY

Ron Beresford 2 Dec 97

Conversion compatibility between the VLA antenna to baseband and the VLBA antenna to baseband entails that the same sky frequencies as well as the same sideband phasing be possible.
For increasing or decreasing sky frequency at the VLA there must be increasing or decreasing frequency at baseband , not necessarily that order respectively. What is important for final correlation of radio data between sites is the VLBA to baseband output must work in an identical sense to the VLA for any chosen observation frequencies within the commonality of reciever frontends provided .

There are many ways to acheive sideband inversion as required.

1. Provide a high side and low side LO and mixer stage at Pie Town
2. Alter the conversion stage 1200MHz and 1800MHz frequencies in the T3 baseband conversion module from low side and high side LO's to high side and low side LO's respectively. Since a T3 is designed to process 4 IF's simultaneously ,sideband inversion on F1 (ChA,ChD) will also cause sideband inversion on F2 (ChB,ChC).
3. Modify tyhe image reject mixer in a T3 by swapping the inverting the hybrid etc. This would make a non standard T3 and be somewhat messy.
4. Design a new baseband image reject mixer . For narrow bandwidths less than a couple of hundred MHz this is readily achieved with off the shelf component(s).

Option 1 is the selected solution ,since some form of downconversion to baseband is required anyway.
This option does mean judicious selection of low side LO's (nominal range 289.9 - 1160.1 MHz) as the fundamental and 3rd harmonics could fall within the converted VLBA 500-100MHz IF 50MHz passband of interest. The upstream VLBA LO's are adjustable in increments of 200 or 300MHz as predicated by L104 (m500 +/- 100) . Hence the 50MHz slot on the sky can be moved 200MHz or 300MHz from the "bad area" at the VLBA IF when this situation arises.
High side downconversion presents no difficulty since the LO's (nominal range 1789.9 - 2660.1MHz) and unwanted USB products aswell as LO feethru are many hundreds of MHz away from the the 500 - 1000MHz VLBA IF passband.

hence $$F_{sky\,VLA} = F_{sky\,VLBA}$$

The "worst" senario will occur when a F12 is used in the VLA , as per X and Q band modes. (F12 12-15GHz k600 +/- 200MHz)
eg Take Incresing baseband frequency with increasing F_{sky} IF Ch A......F8 = 300MHz BPF cf = 1325MHz

thus for VLA $$F12 -(F3 \times 3 - F_{sky\,Q\,VLA}) - L6 + F8 = 1200 + L_{bba} + BW/2$$

for VLBA $$(F_{sky\,Q\,VLBA} - L104_2 \times 3) - L104_1 + L6_{VLBA} = 1200 + L_{bba} + BW/2$$

$$F12 -(F3 \times 3 - F_{sky\,Q\,VLA}) - L6 + F8 = (F_{sky\,Q\,VLBA} - L104_2 \times 3) - L104_1 + L6_{VLBA}$$

$$F12 - 3\,F3 + F_{sky\,Q\,VLA} - L6 + F8 = F_{sky\,Q\,VLBA} - 3\,L104_2 - L104_1 + L6_{VLBA}$$

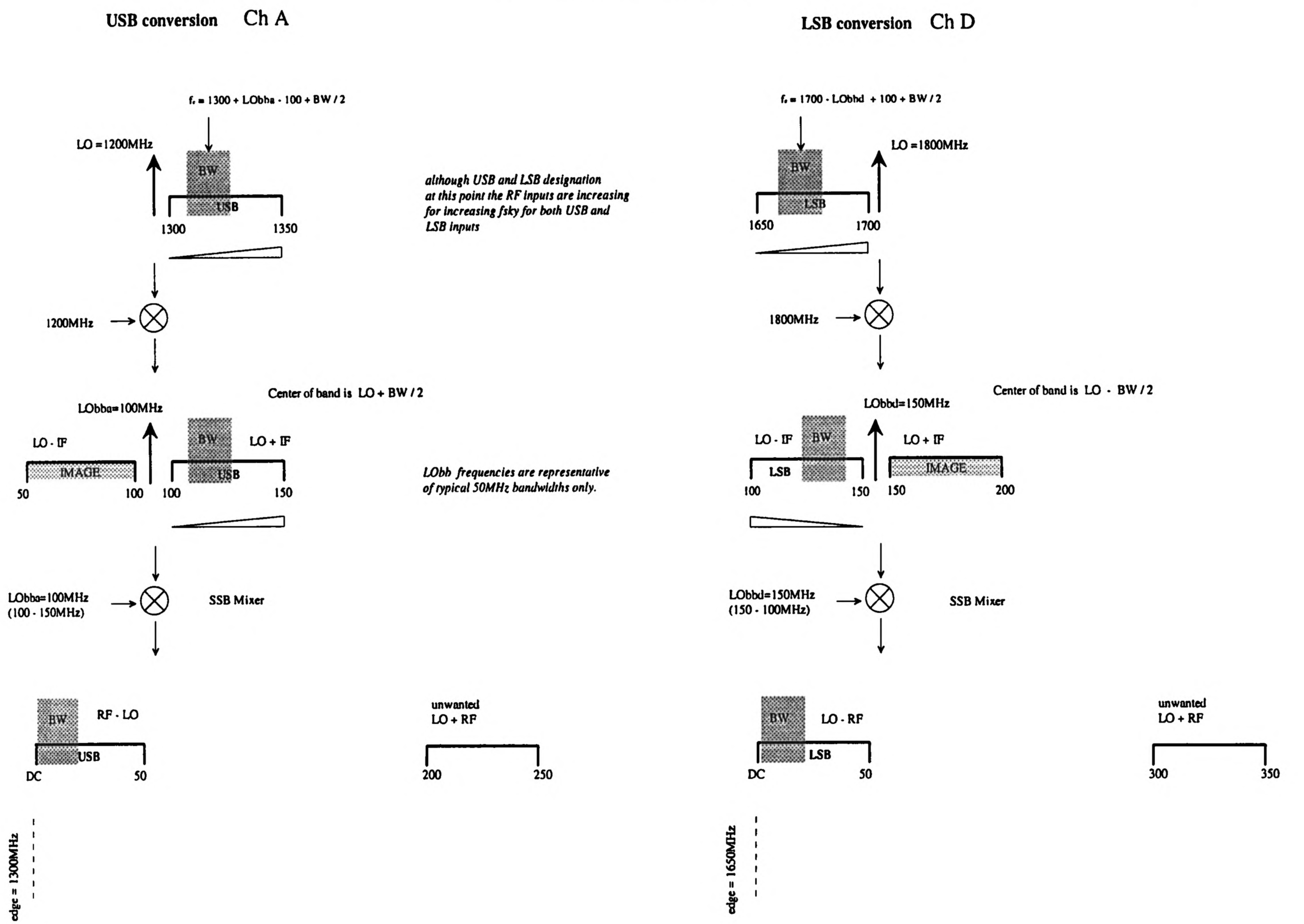
$$F12 - 3\,F3 - L6 + F8 = L6_{VLBA} - 3\,L104_2 - L104_1$$

$k_1\,600 \pm 200$ $\quad 3\,k_2\,600 \pm 100$ $\quad k_3\,50 \pm 10.1 \pm \Delta$ $\quad 300$ $\quad n\,50 \pm 10.1 \pm \Delta$ $\quad 3m_2\,500 \pm 100$ $\quad m_3\,500 \pm 100$

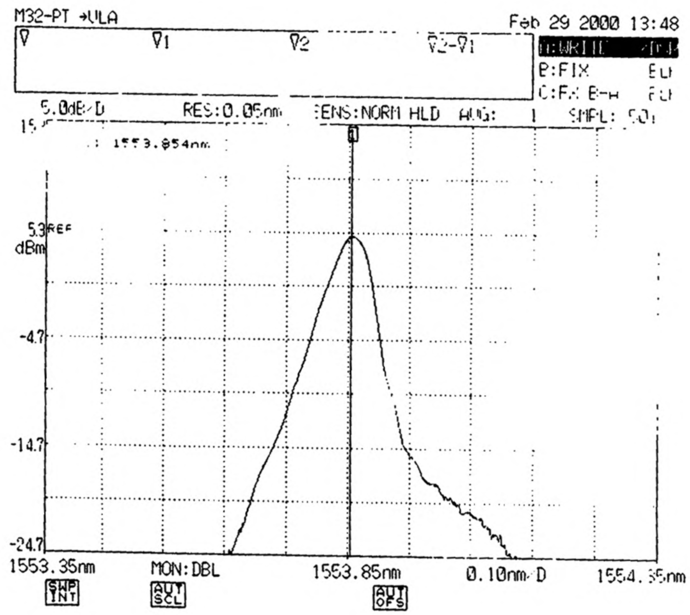
NB for this sideband sense $\Delta v_{lba} = - \Delta v_{la}$

BASEBAND CONVERSION PRINCIPLES

Ron Beresford 25 Nov 97

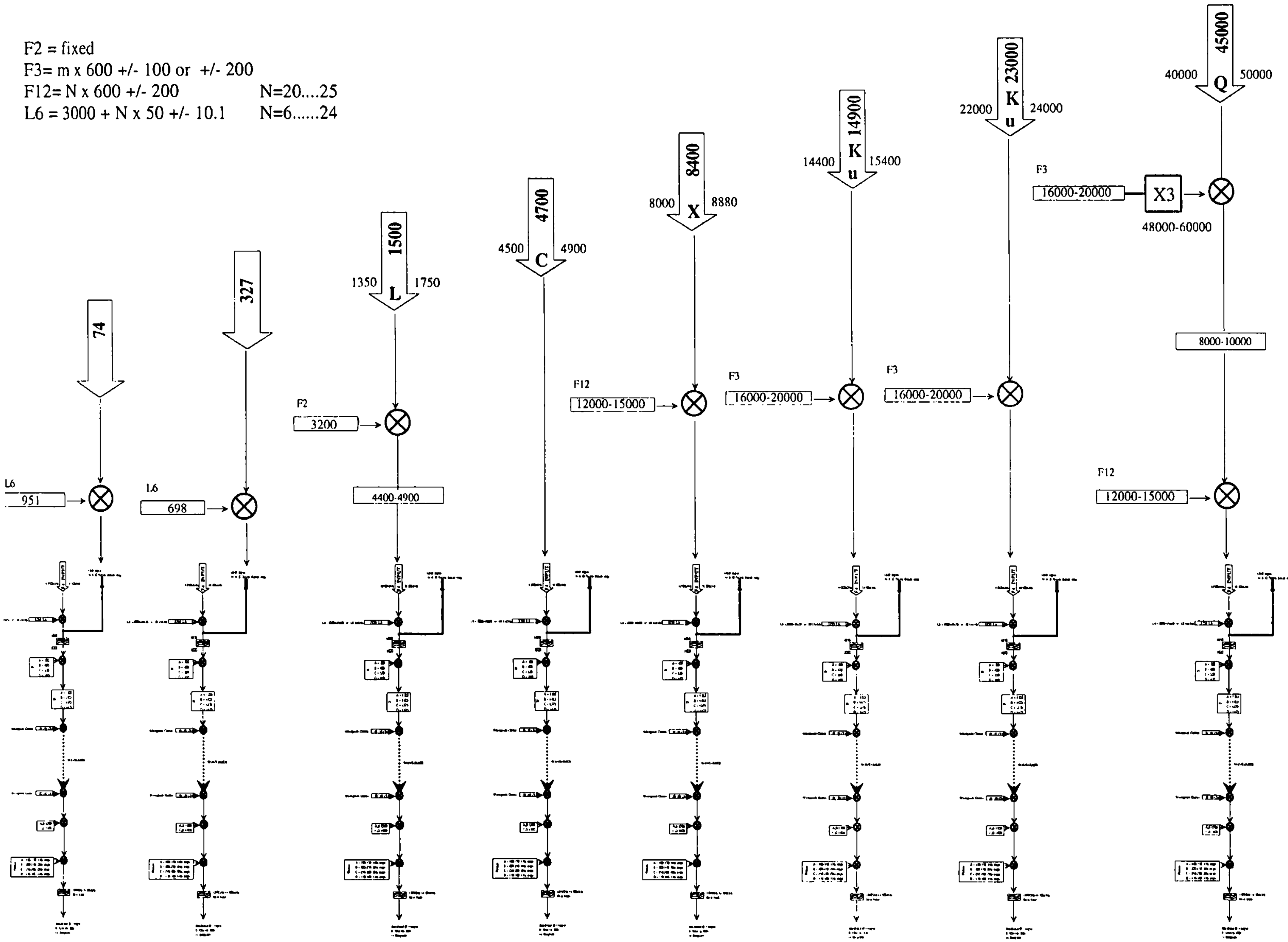


Kt out @ PT, From PT



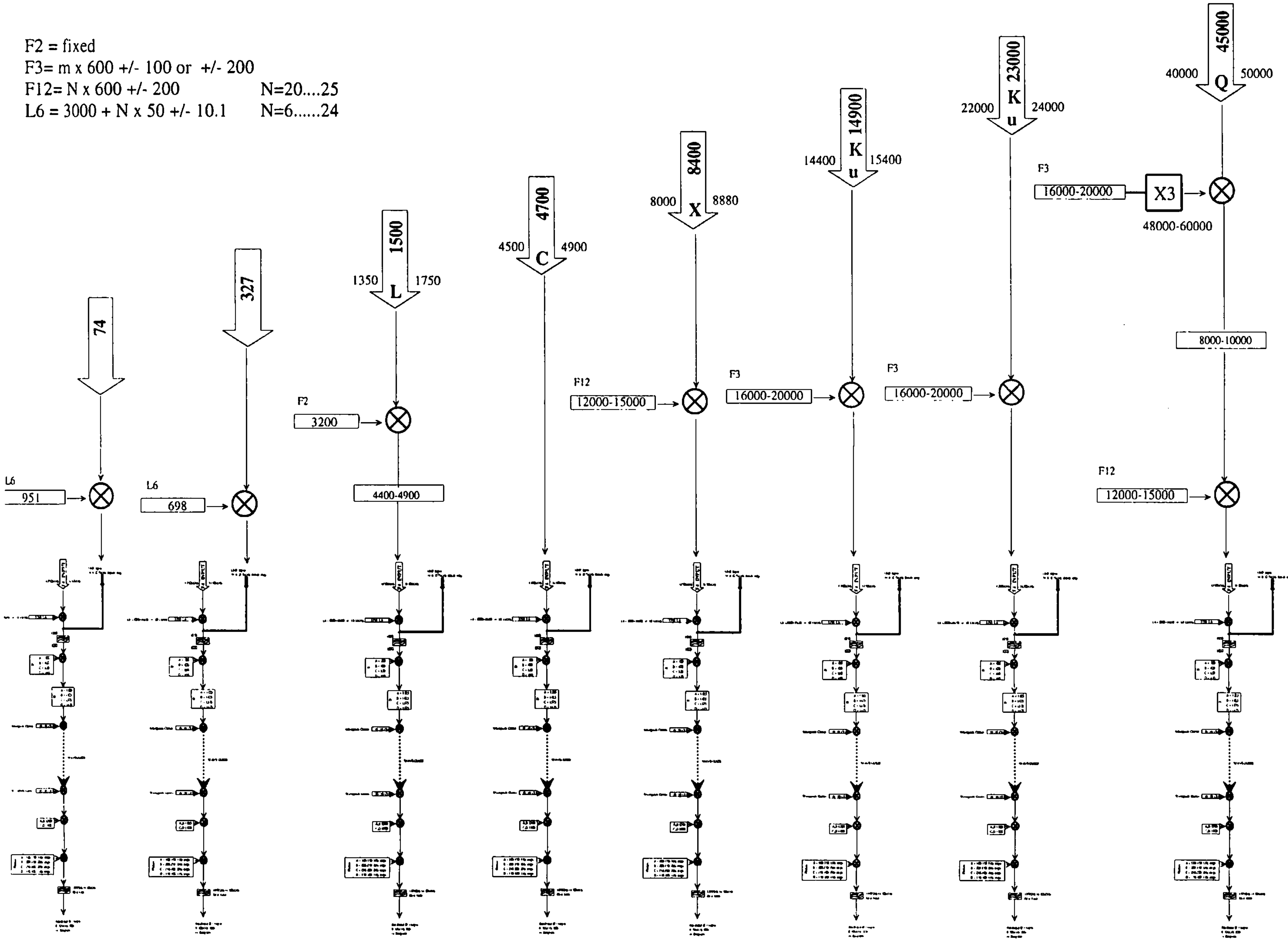
VLA Conversion Process Overview 74 to 45000 MHz Bands

F2 = fixed
F3= m x 600 +/- 100 or +/- 200
F12= N x 600 +/- 200 N=20....25
L6 = 3000 + N x 50 +/- 10.1 N=6......24



Ron Beresford 7 Nov 97

VLA Conversion Process Overview 74 to 45000 MHz Bands



Ron Beresford 7 Nov 97

VLA Conversion Process Overview 74 to 45000 MHz Bands

F2 = fixed
F3= m x 600 +/- 100 or +/- 200
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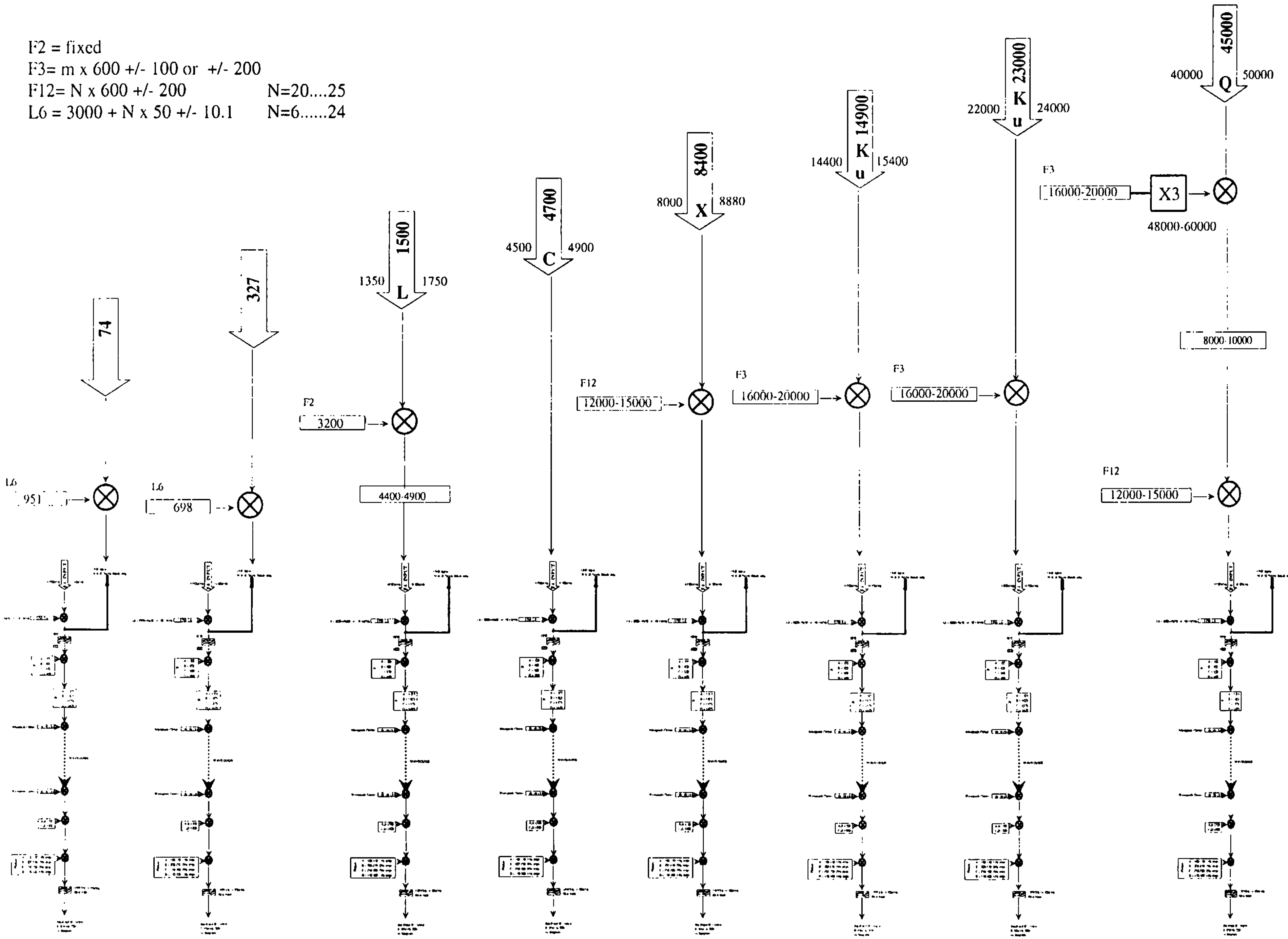
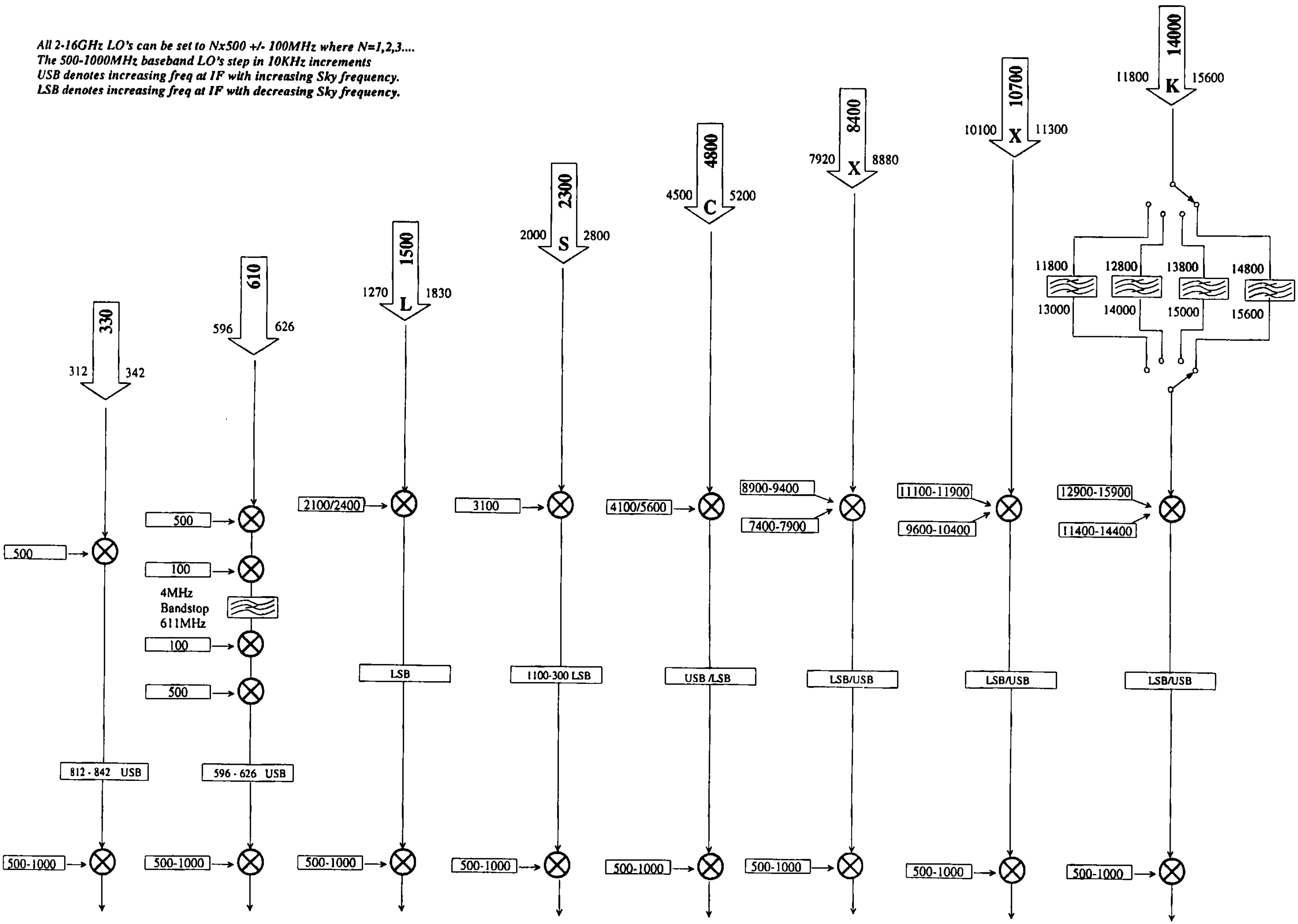


Ron Beresford 7 Nov 97

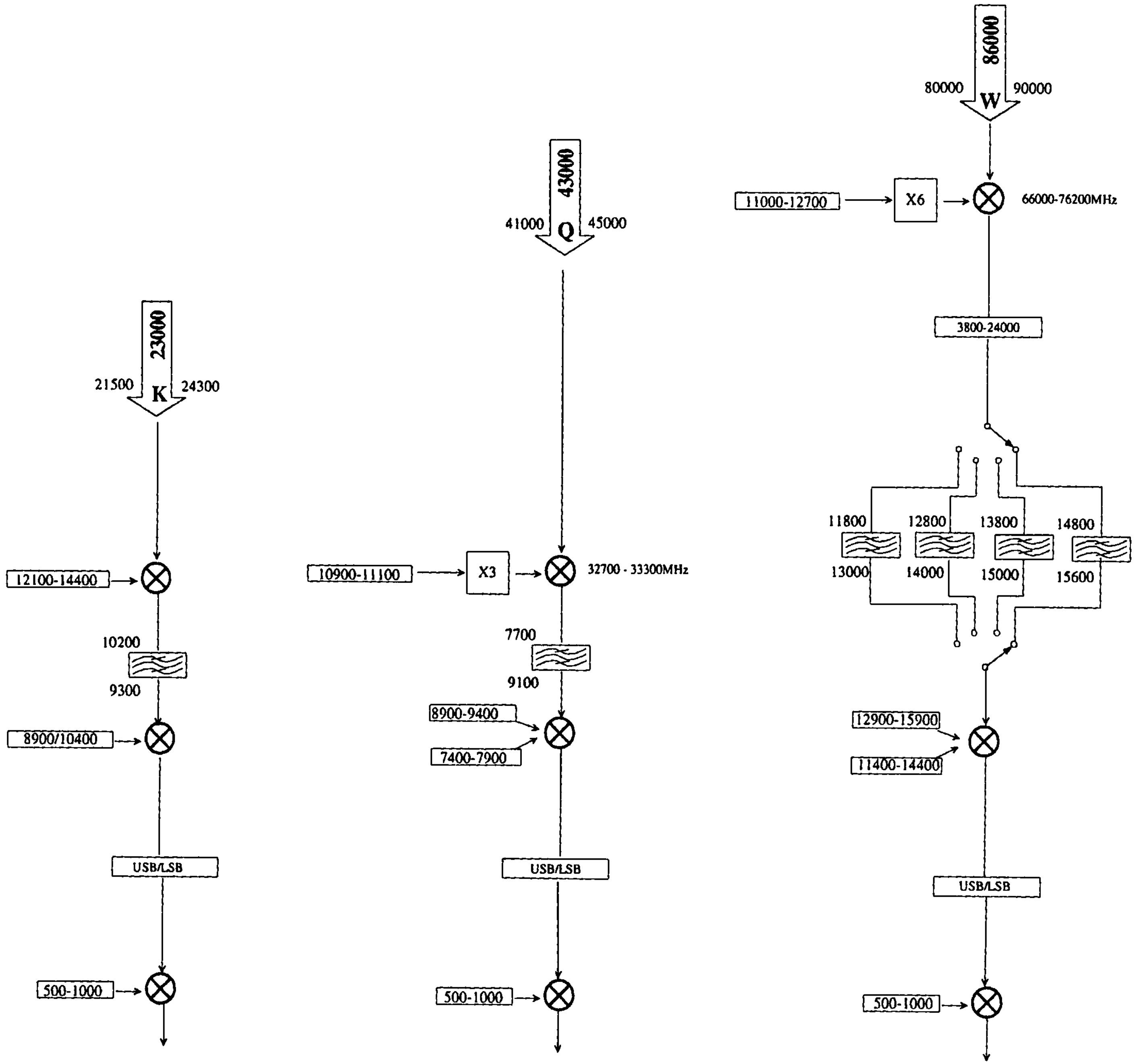
VLBA (Pie Town) Conversion Process Overview 330 to 14000 MHz Bands

All 2-16GHz LO's can be set to Nx500 +/- 100MHz where N=1,2,3....
The 500-1000MHz baseband LO's step in 10KHz increments
USB denotes increasing freq at IF with increasing Sky frequency.
LSB denotes increasing freq at IF with decreasing Sky frequency.

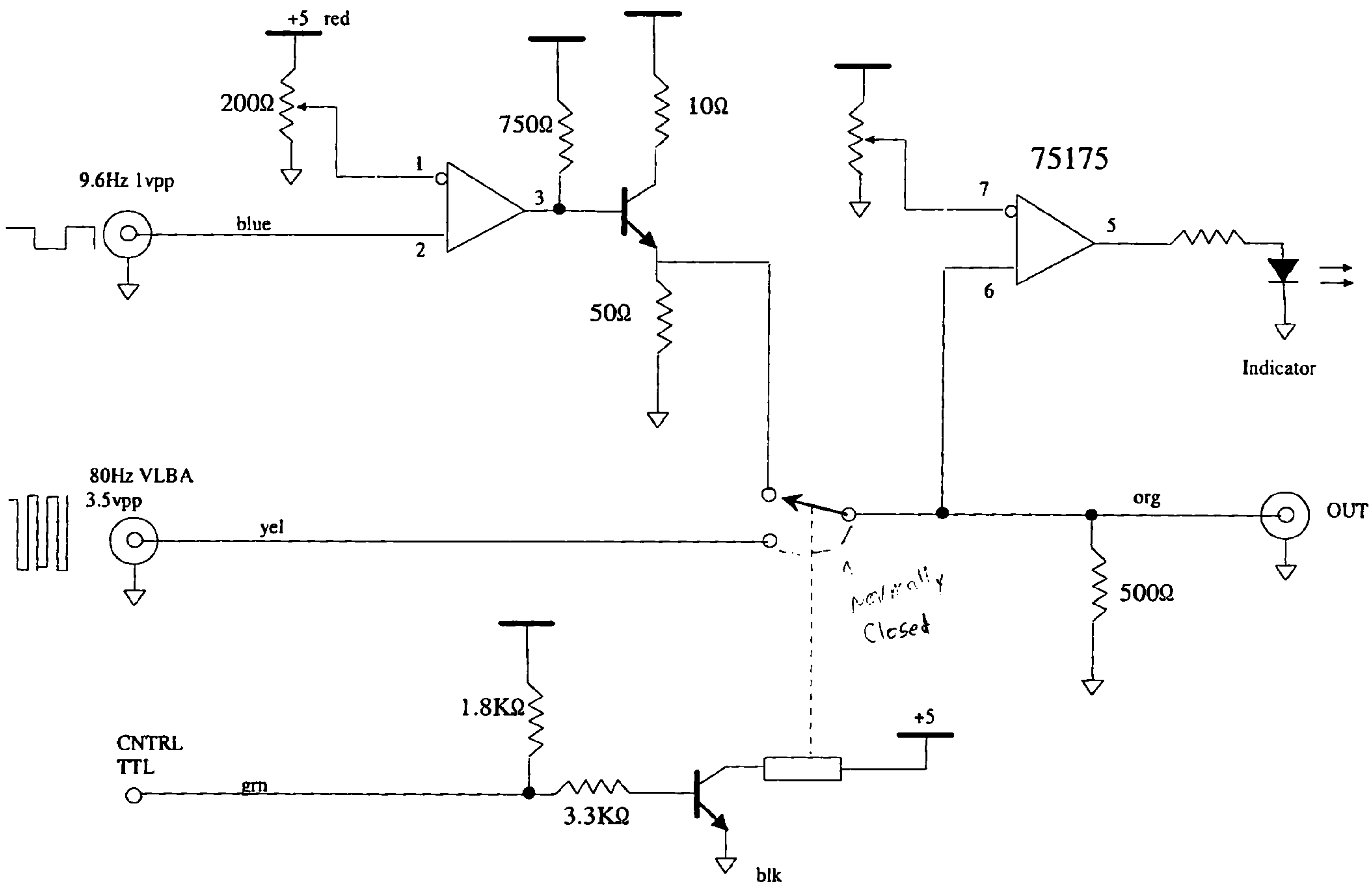


Ron Beresford 7Nov 97

VLBA (Pie Town) Conversion Process Overview 23000 to 86000 MHz Bands



NOISE DIODE CHANGEOVER CCT



rjb 30 Sept 99

undesireable signal loss, was allowed for to meet this target. However ,the initial two filter BWDM filter system used exceeded manufacturers specifications at 1553.6nm ,the analog laser wavelength ,so this optional third VLA clean up filter was not required.

The E-tek range of 3 port WDM cascadeable thin film filters consist of a bandpass material sandwiched between 2 fiber collimators and three pig tailed fiber ports.
The filter is designed to transmit a specific band of light λ_P from port C to port P with low insertion loss. All other incident light is tilted by a small angle so the reflected beam from the filter is directed to port R with even lower insertion loss (<0.2dB). Hence an essentially wide flat spectrum of light appears at R with a notch in that spectrum of λ_P.
Isolations are typically 12- 20dB for λ_P crosstalk into port R and 30-46dB for λ_R crosstalk into port P.

Importantly and less obvious is the directivity of the device defined as the amount of light at λ_P at P appearing on port R (typically better than 50dB down). In fact it is this feature that has enabled such a low component count network to be constructed.

The thin film DIF is completely bi-directional.

The key component of the filter is a a thin film dielectric coating on a glass or polymer substrate. Interference coatings consist of alternating thin layers of high and low index dielectric materials such as Ta_2O_5 and SiO_2. Multiple coating layers form all dielectric cavities that selectively transmit or reflect light depending on the wavelength. Bandpass filters can be made in any bandwidth from 0.7nm to 60nm ,with wide flat tops and steep sidebands. The passband width is defined as the 0.5dB bandwidth and the stopband as the 20dB bandwidth.
These characteristics are quite easily seen using the HP 83437A EELED broadband light source and Ando OSA.

Before final installation tests were made for the nonlinear optical process known as Four-wave mixing. Akin to third order intermodulation in RF systems ,FWM is a potentially troublesome in low dispersion ,highly coherent laser systems were the optical "wavefronts" can phase up and generate new wavelengths. $\lambda_{new} = \lambda_1 + \lambda_2 - \lambda_3$. The PT link uses a high dispersion fiber at 1800ps/nm. As an academic exercise studies were done using the Virtual Photonics Design Suite PTDS CAD with three optical carriers injected into one end of the PT fiber , very much a worst case scenario . Simulations revealed potential FWM wavelengths 50dB down from the optical analog carrier at the far end and 10nm away. Potential FWM wavelengths were 45dB down and 1nm away from received digital channels .

The FWM test was implemented on the bench using actual laser devices and the OSA at the far end. No FWM products were observed with the 70dB instrument dynamic range. It was concluded with the actual PT-VLA link configuration , two lasers at one end of the link and a single laser at the other ,ie VLA. the probability of FWM is even further reduced. In conclusion FWM was to some degree considered irrelevant for such a small number of optical wavelengths and large spacings.

All laser devices used have built-in optical isolation with upto 30dB isolation. DFB lasers can behave erratically with back reflected energy into the laser. The backward travelling signals for the digital lasers was typically better than 50dB down. For the analog laser where any perturbations on the optical spectra cannot be tolerated an additional 40dB optical isolator was added reducing backward traveling spectra to approximately –100dB or better.

Based on the 3 port cascadeable DIF component ,for the PT link an asymmetric ,high isolation 1 x 3 mux/demux network is constructed.

OPTICAL MUX / DEMUX

OPTICAL MULTIPLEXER / DEMULTIPLEXER

Cornerstone to the implementation of the PT link project was the capacity to have several optical carriers coexist on a single fiber core. Increasing the number of optical transmission channels is an approach gaining acceptance as a straight forward economical solution to providing more bandwidth in many fiber applications . The dense wavelength division multiplexing technique (DWDM) is seen as more fully utilizing the intrinsic capacity of fiber when compared to increasing the speed of data through time division multiplexing (TDM). The use of DWDM in the PT link was influenced primarily by cost of fiber rental and the use of new innovative optical methods applicable to future construction projects.

Three wavelengths are multiplexed /demultiplexed using DWDM.

The high power laser (+10dBm at Mux) from the PT site to the VLA at 1553.6nm .
The digital low power laser (+2dBm at Mux) from the PT site to the VLA at λ_2 1530nm.
The digital low power laser (+2dBm at Mux) from the VLA site to PT at λ_3 1535nm.

DWDM techniques are now well understood and used extensively by the telecommunications industry.

Several filtering options were considered for the Mux/Demux networks.

a.	Thin Film Dichroic Interference Filters	DIF
b.	Bragg Grating Filters	FBG
c.	Fused Biconic Taper , Hybrid Fused Cascaded Fiber	FCF
d.	Array Waveguide Filters	AWG

Fused Biconic Taper filter networks were considered but the precise sinusoidal passband characteristics meant any misalignment in laser wavelength would compromise maximum signal transmission. This was particularly relevant to the analog transmission window where a variety of lasers ,DFB and Erbium solid state were possibilities with wavelengths not necessarily coinciding with the ITU grid for the high power devices required. Although for the small number of channels involved they could be made quite cheap.

Bragg Grating filters were not offered as a standard off the shelf package and have potentially serious back reflection issues that would require extra expensive devices such as optical isolators.

Array Waveguide filters are still pretty much a laboratory device ,and although they hold great promise for inexpensive highly integrated assembly ,in the quantities required for the PT project it would have been very expensive. AWG filters also have serious thermal stability issues.

Thin film DIF filters available from E-Tek Dynamics were considered a mature product line offering a 3 port ,2 wavelength band device that is stable with temperature for approximately $600 a piece.
The devices selected either DWFI (narrow band ITU) or BWDM broadband offer low insertion loss (<0.7dB) between any two ports with a flat transmission window, approximately 1nm width used in the digital bidirectional link . Alignment of the digital DFB lasers to the required ITU operating wavelength was relatively easy to adjust with temperature at 0.1nm / °C.
Enormous isolation between the the digital ITU WDM channels is realized by the filter 20dB/nm roll off as the digital lasers are spaced by 5nm .
The signal to noise affecting the BER of the link becomes limited by the link power budget ,extinction ratio and the 32dB ORL presented by the Rayleigh Backscatter for the 104km "long line" and not from effects such as intersymbol interference from wavelength crosstalk.

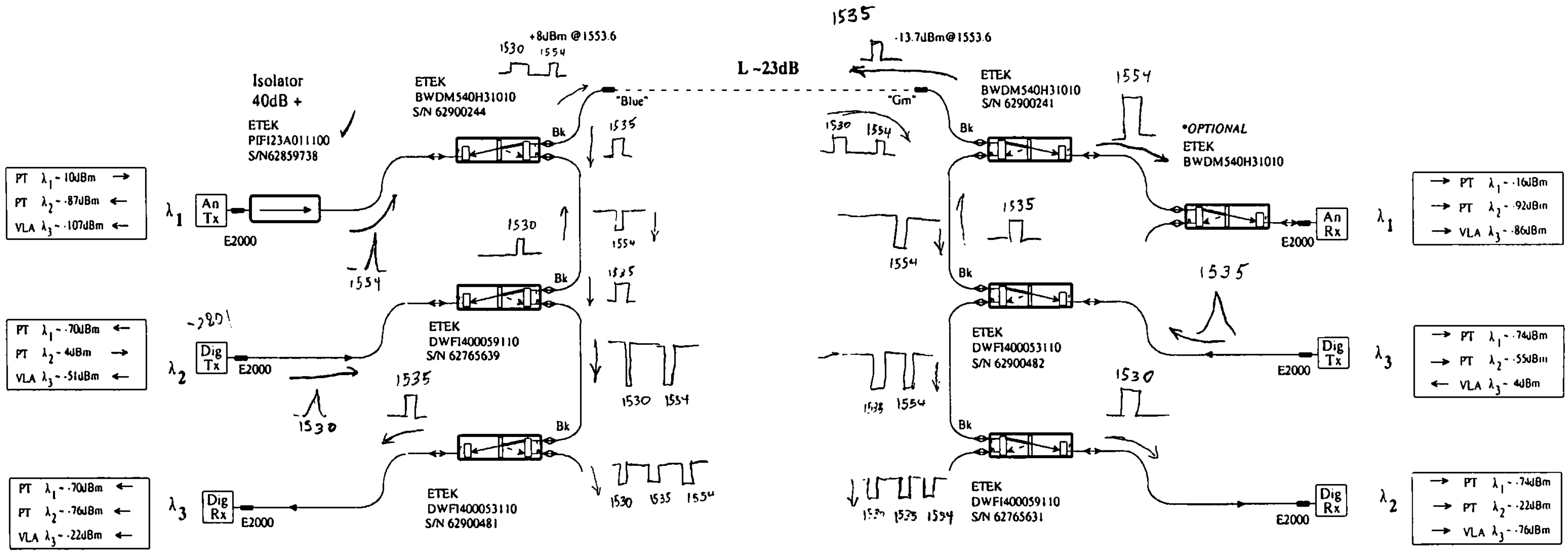
Crosstalk does however become a more involved issue in the context of the high dynamic range analog channel.
With the analog optical carrier modulated at ~1% to maintain linearity requirements for the RF from PT back to the VLA the RF is in optical sidebands at –42dBm at the VLA photodetector . Interfering spectra (ie crosstalk) must be atleast 20dB electrical (10dB optical) below this figure to meet link specifications. Hence no interfering spectra can exceed –49dBm. An optional additional BWDM filter ,with further

ITU STANDARD FIBER-OPTIC TELECOMMUNICATION CHANNEL: FREQUENCY AND WAVELENGTHS

CH	FREQUENCY (GHz)	Wavelength (nm)	CH	Frequency	Wavelength (nm)
15	191500	1565.50	44	194400	1542.14
16	191600	1564.68	45	194500	1541.35
17	191700	1563.86	46	194600	1540.56
18	191800	1563.05	47	194700	1539.77
19	191900	1562.23	48	194800	1538.98
20	192000	1561.42	49	194900	1538.19
21	192100	1560.61	50	195000	1537.40
22	192200	1559.79	51	195100	1536.61
23	192300	1558.98	52	195200	1535.82
24	192400	1558.17	53	195300	1535.04
25	192500	1557.36	54	195400	1534.25
26	192600	1556.55	55	195500	1533.47
27	192700	1555.75	56	195600	1562.68
28	192800	1554.94	57	195700	1531.90
29	192900	1554.13	58	195800	1531.12
30	193000	1553.33	59	195900	1530.33
31	193100	1552.52	60	196000	1529.55
32	193200	1551.72	61	196100	1528.77
33	193300	1550.92	62	196200	1527.99
34	193400	1550.12	63	196300	1527.22
35	193500	1549.32	64	196400	1526.44
36	193600	1548.51	65	196500	1525.66
37	193700	1547.72	66	196600	1524.89
38	193800	1546.92	67	196700	1524.11
39	193900	1546.12	68	196800	1523.34
40	194000	1545.32	69	196900	1522.56
41	194100	1544.53	70	197000	1521.79
42	194200	1543.73	71	197100	1521.02
43	194300	1542.94	72	197200	1520.25

Frequencies are accurate values, wavelengths are dependent on the media properties.

HIGH ISOLATION OPTICAL MUX / DEMUX



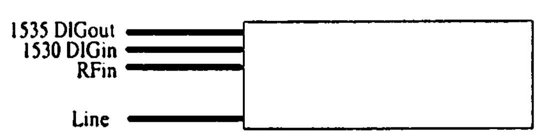
λ_1 1553.6 nm

λ_2 1530 nm

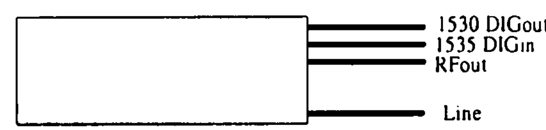
λ_3 1535 nm

Pie Town

VLA



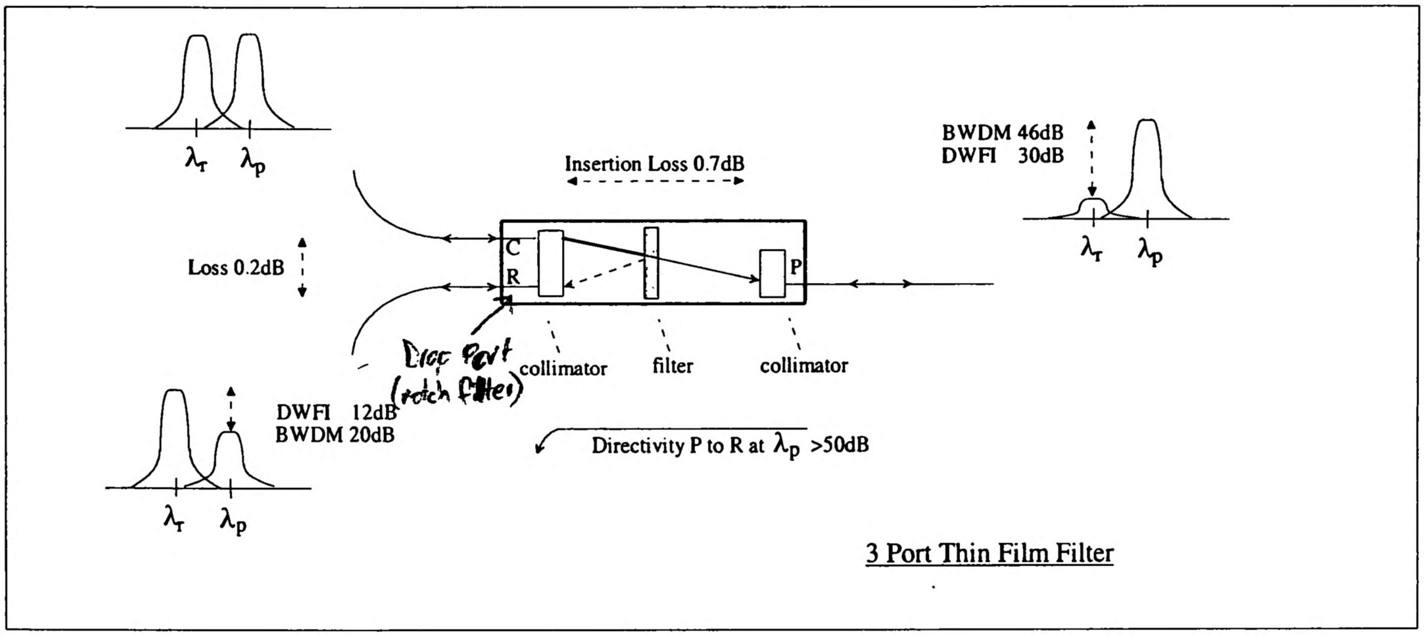
PT MUX SPLICE TRAY

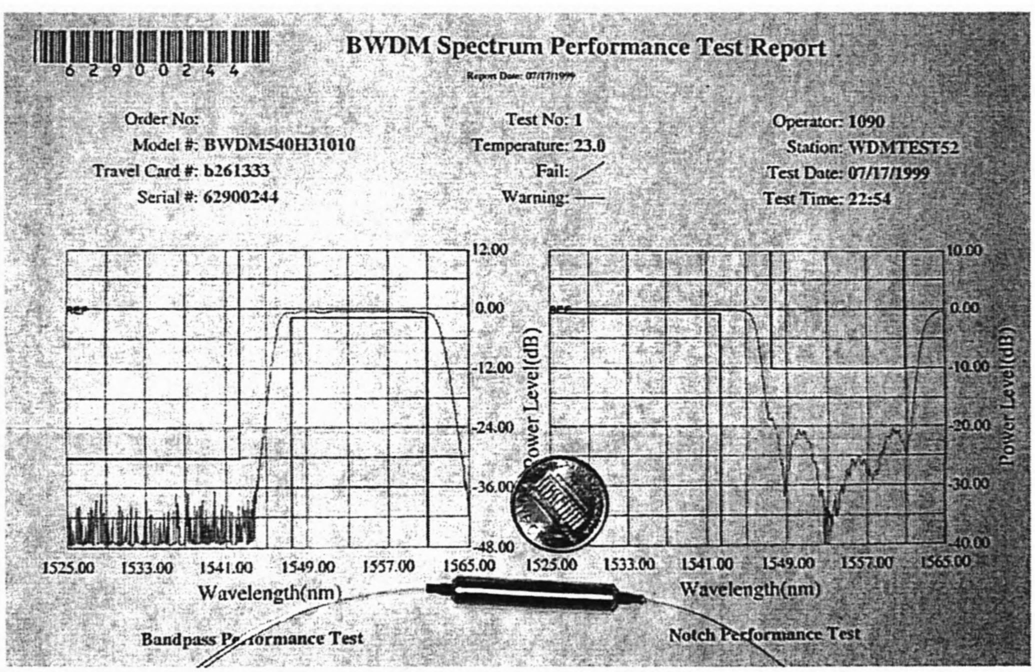


PT MUX SPLICE TRAY

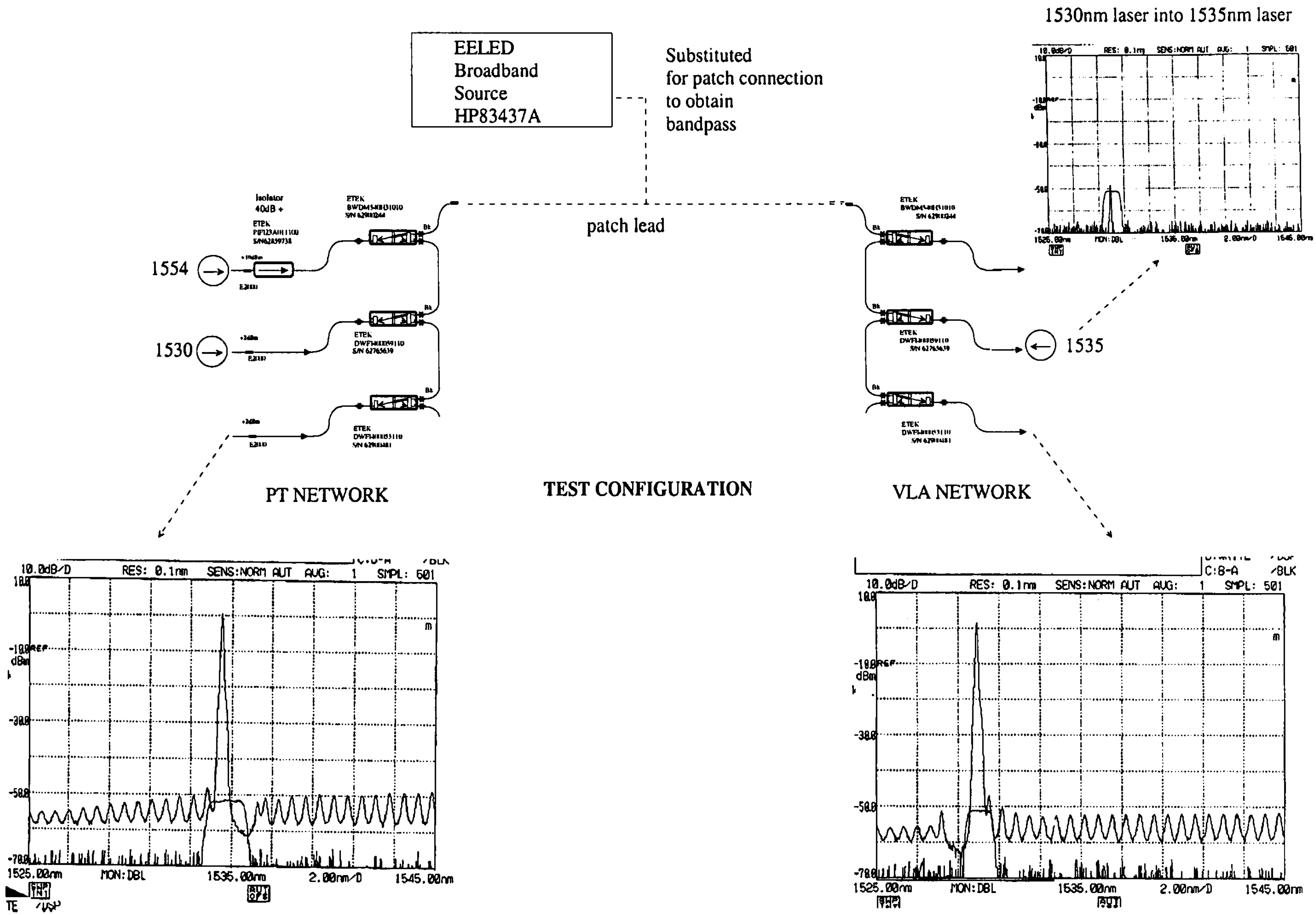
rjb 10th Nov 99

HIGH ISOLATION OPTICAL MUX /DEMUX

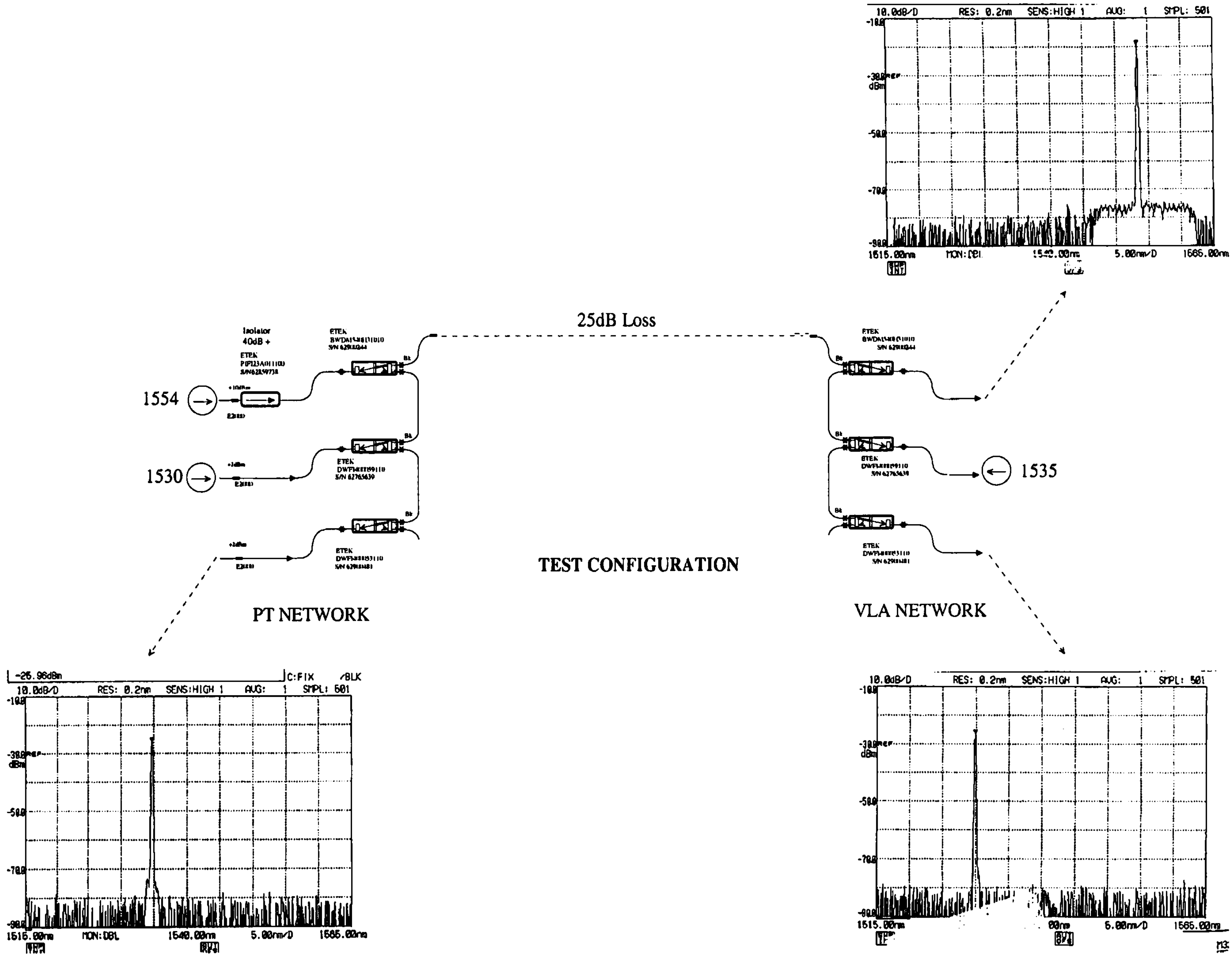




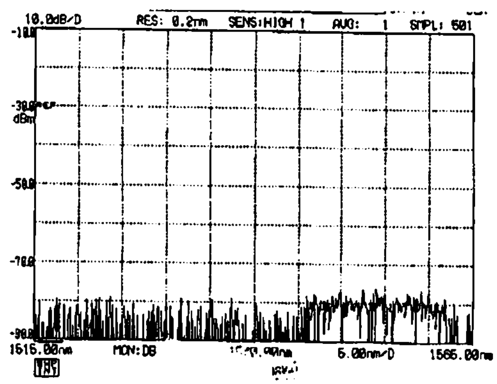
DIGITAL CHANNEL ALIGNMENT OVERLAY



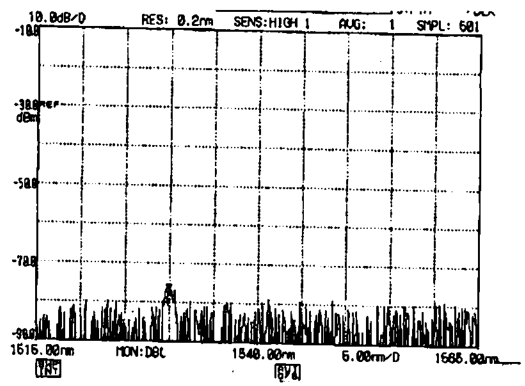
RECEIVE PORTS WITH 25dB FIBER



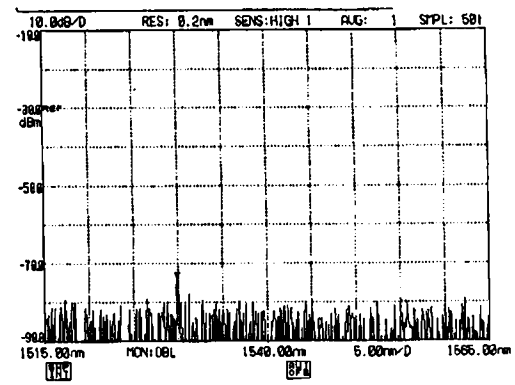
LASER PORTS ISOLATION



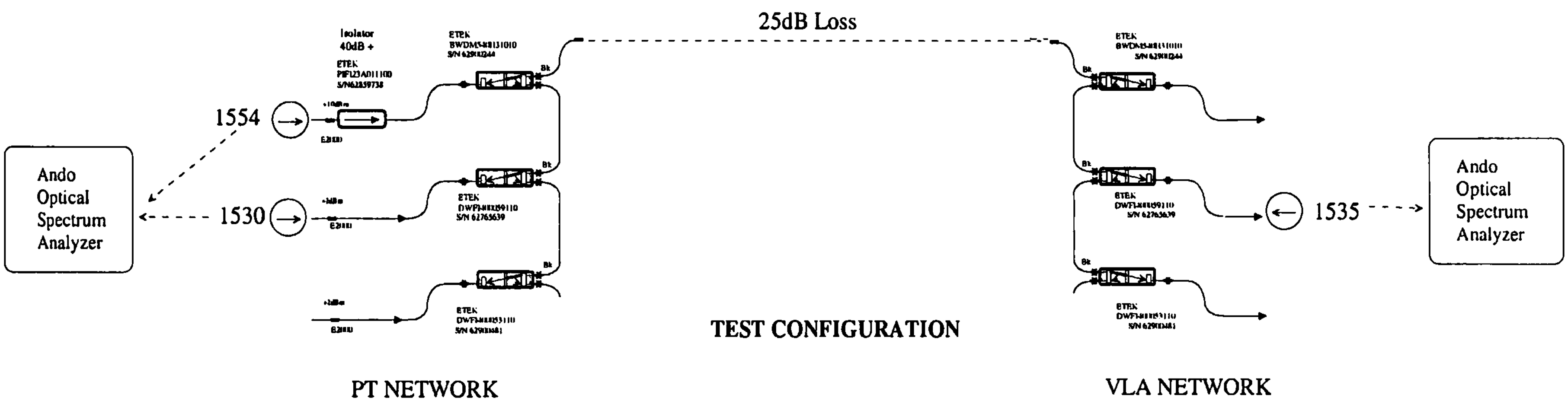
1530nm and 1535nm lasers feeding back into 1554nm PT laser port.



1554nm PT High power analog laser and VLA 1535nm laser as measured at the PT 1530nm laser port.



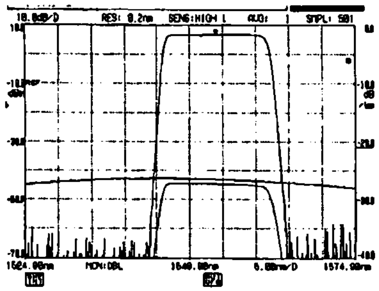
1554nm PT High power analog laser and PT 1530nm laser as measured at the VLA 1535nm laser port.



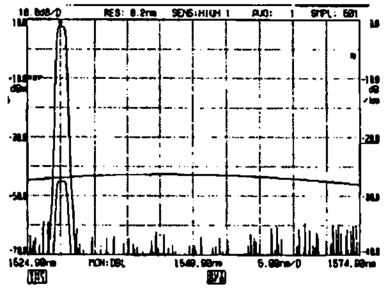
TEST CONFIGURATION

OPTICAL NETWORK LOSS EVALUATION

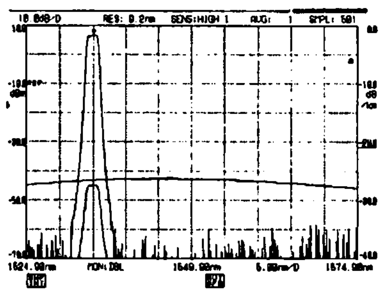
PT Analog Channel
Loss~ 1.6dB



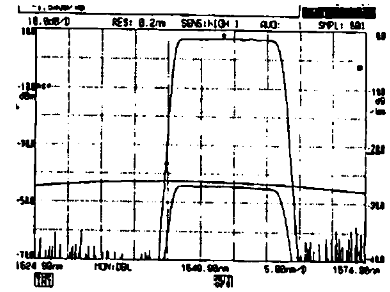
PT 1530nm Channel
Loss ~ 1.2dB



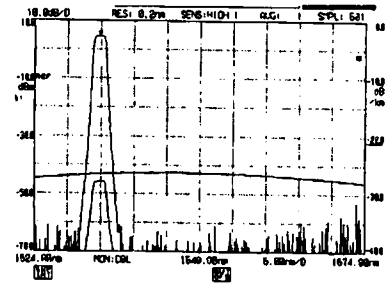
PT 1535nm Channel
Loss ~ 1.7dB



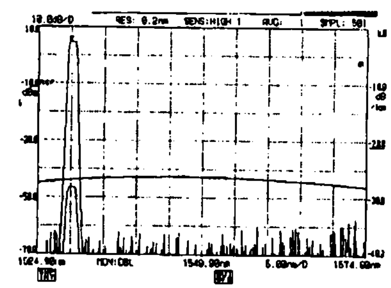
VLA Analog Channel
Loss~ 2.5dB

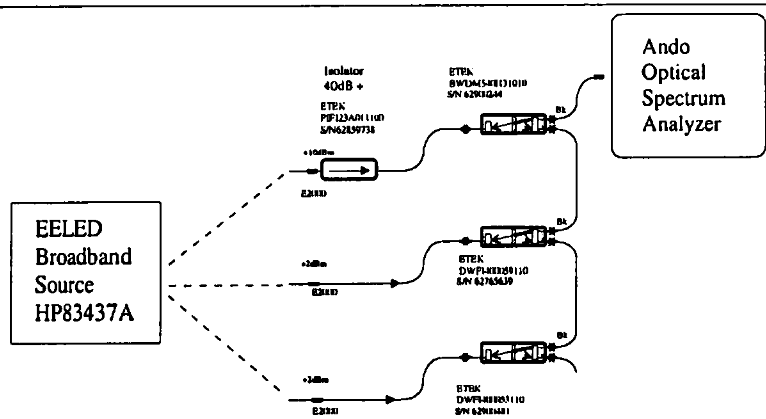


PT 1535nm Channel
Loss ~ 2.6dB

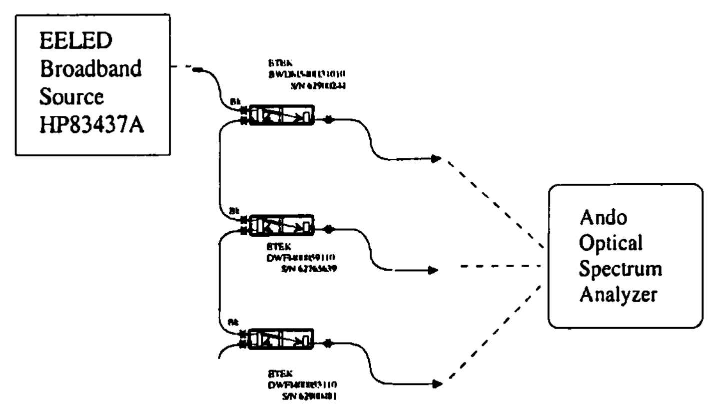


PT 1530nm Channel
Loss ~ 1.5dB



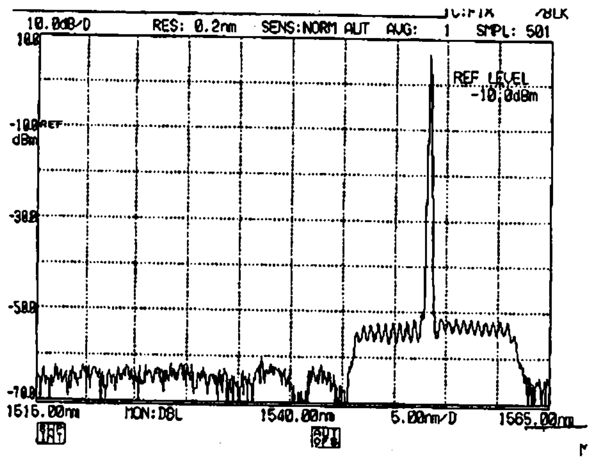


TEST CONFIGURATION PT NETWORK

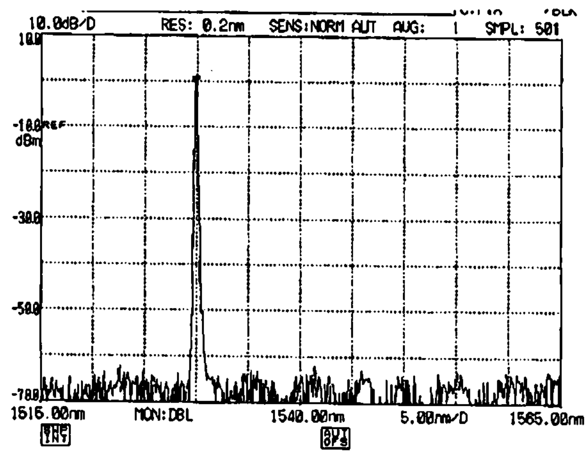


TEST CONFIGURATION VLA NETWORK

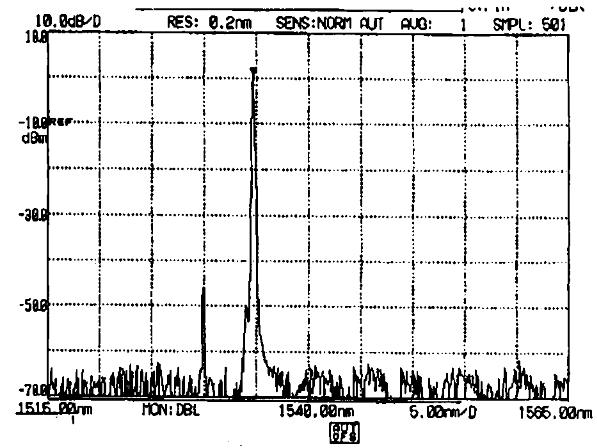
CROSSTALK EVALUATION



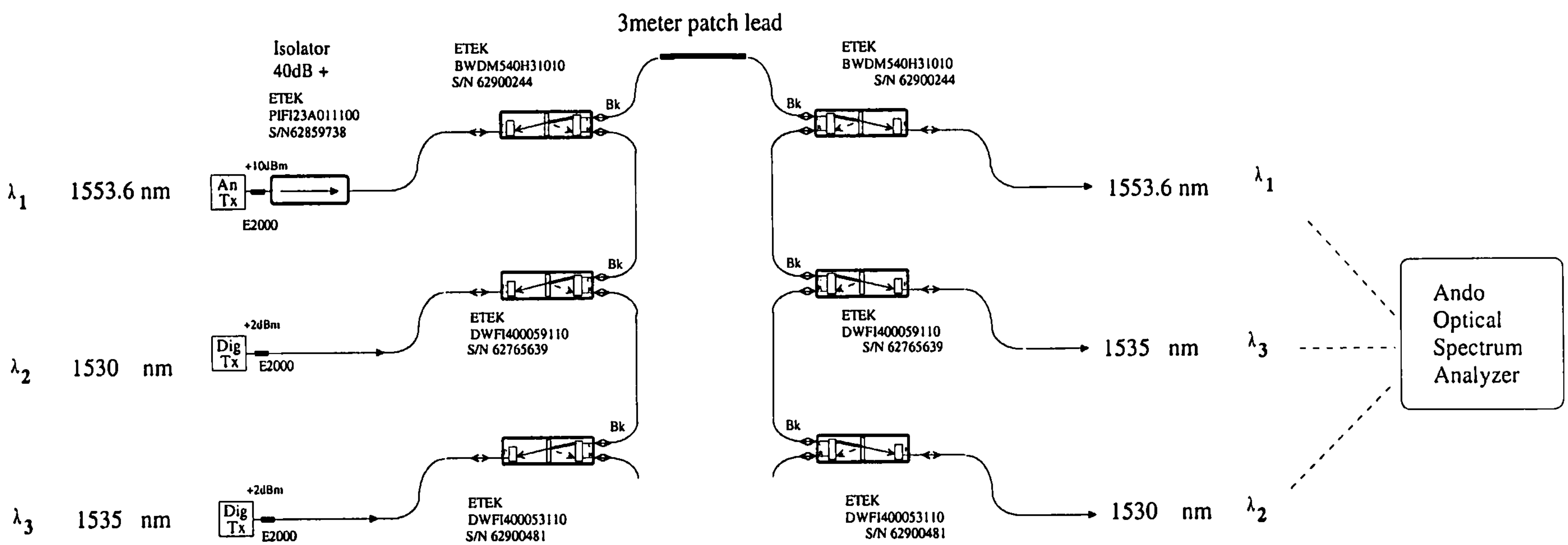
PLOT of 1554nm Channel



PLOT of 1530nm Channel



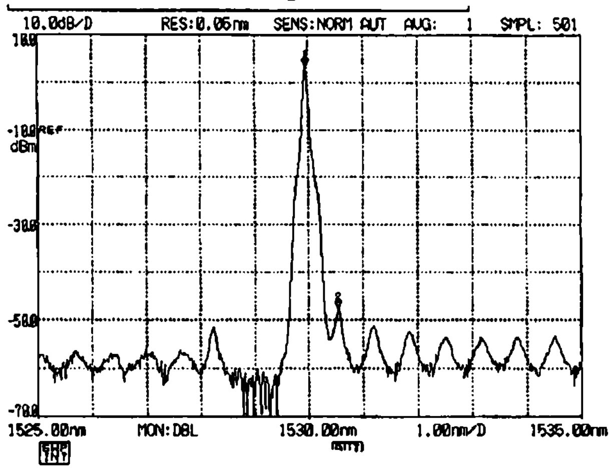
PLOT of 1535nm Channel



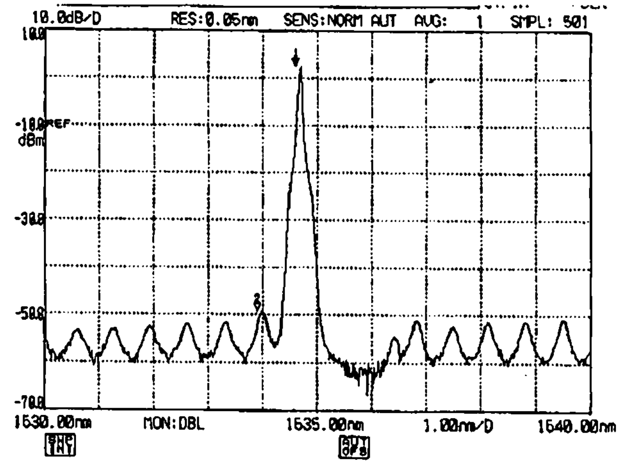
TEST CONFIGURATION

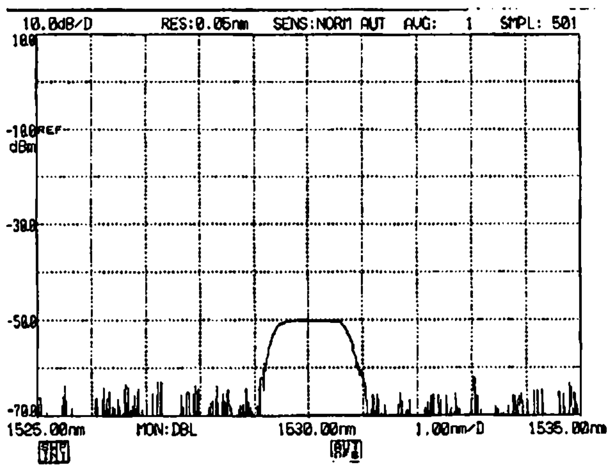
ALIGNMENT of λ2 λ3 optical drop filters

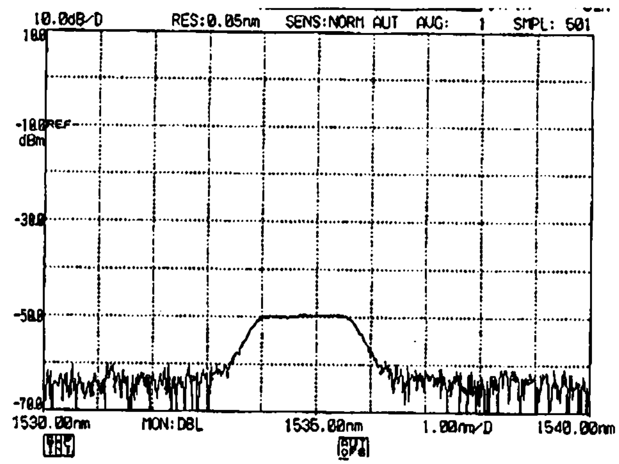
1530nm Alignment

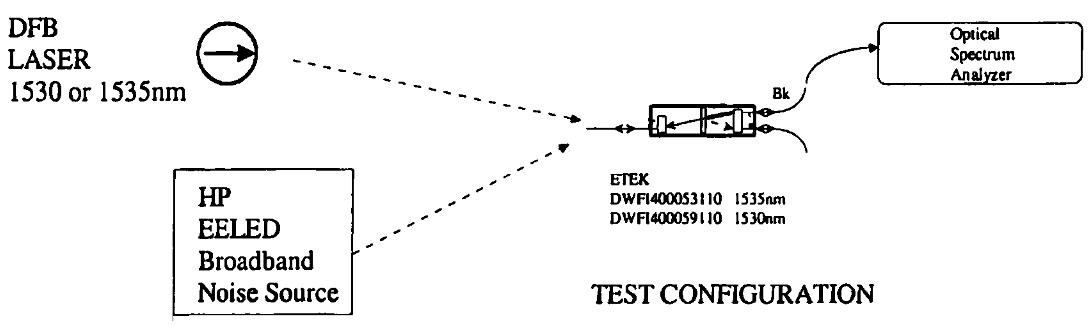


1535nm Alignment



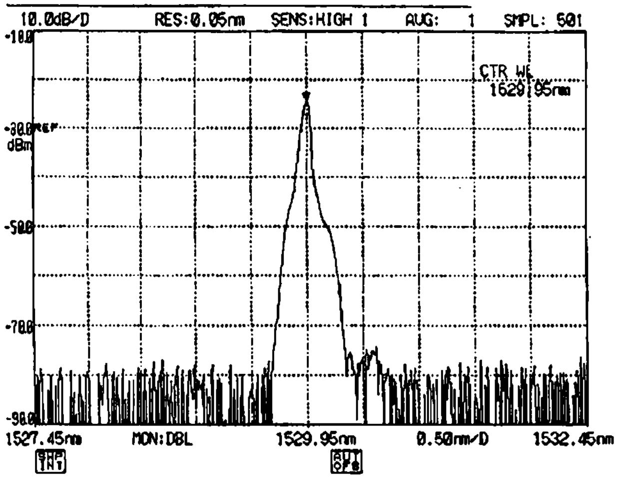




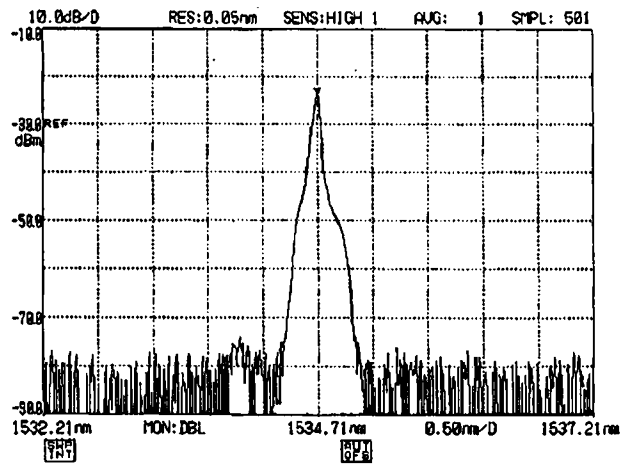


TEST CONFIGURATION

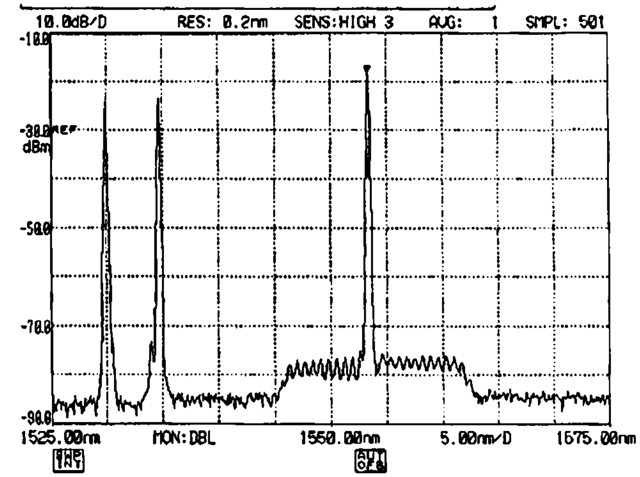
COUPLING λ1 λ2 λ3 into a SMF



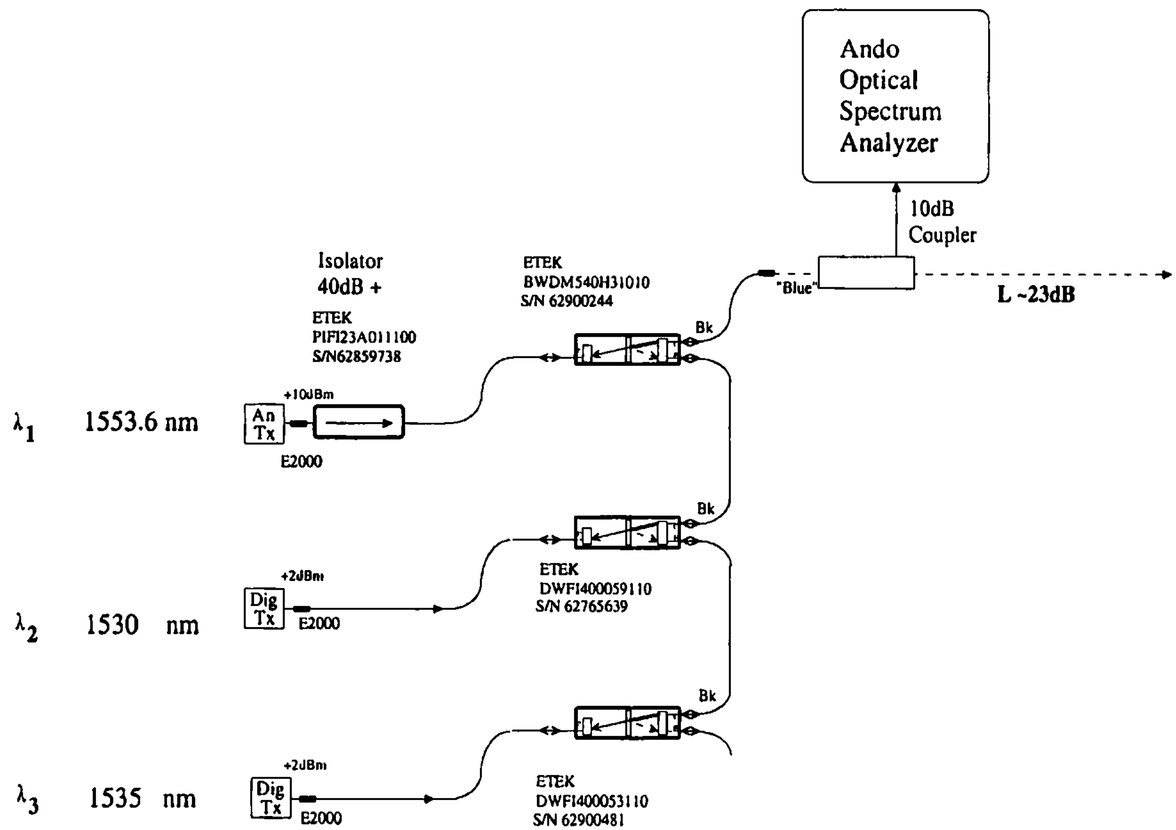
PLOT of 1530nm DFB laser



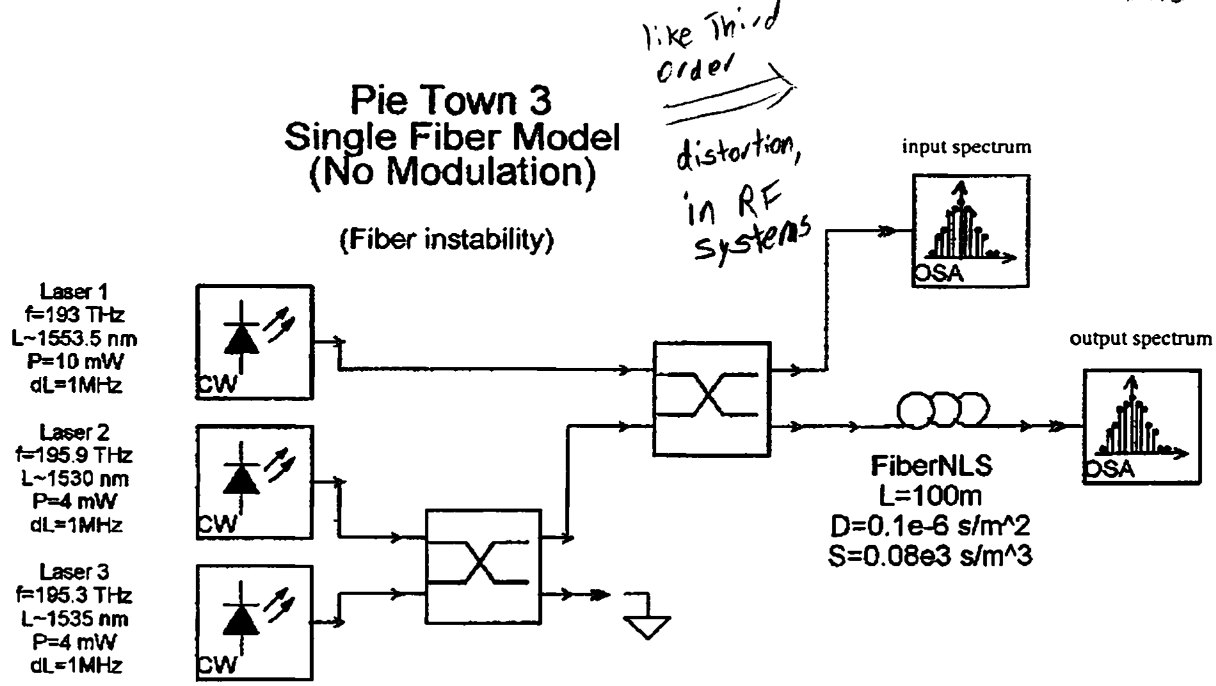
PLOT of 1535nm DFB laser

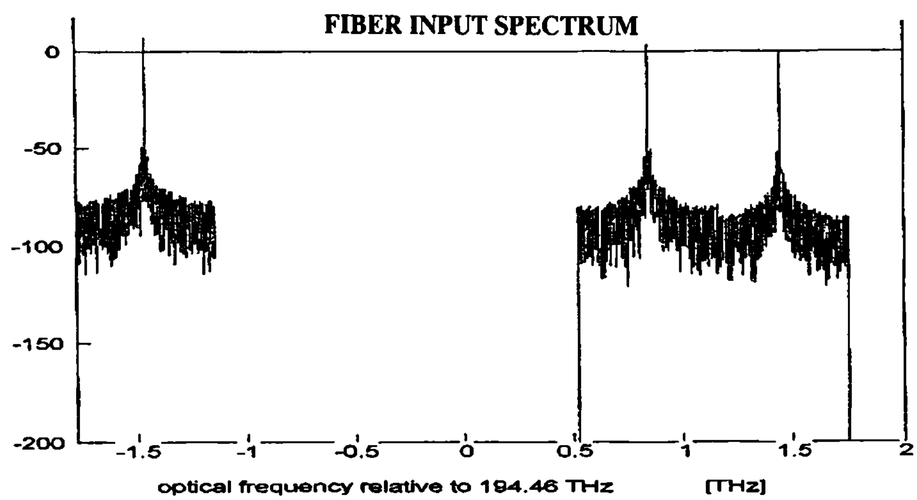


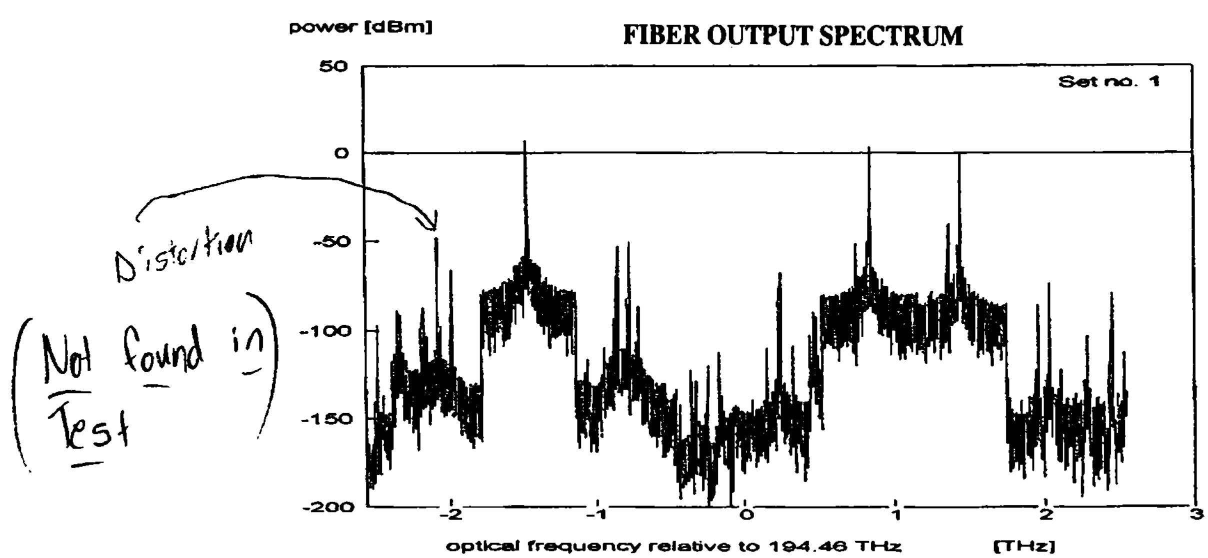
Plot of all Lasers after being Muxed onto a songle fiber for test purpose only.



PTDS CAD SIMULATION OF FOUR WAVE MIXING – Dan Edmavis







DIGITAL TRANSCEIVER M32

DIGITAL TRANSCEIVER MODULE – M32

A digital transceiver module consists of two cards, the G-link card and the fiber optic modem card. A digital transceiver module is required at each end of the PT link for transmission of VLA waveguide synchronization ,noise diode and Monitor Control System data and other miscellaneous signals if desired.

The G-link Card

The G-link card uses the LSI Hewlett Packard HDMP-1022 Tx and HDMP-1024 Rx ,80 pin Mquad chip set pair. The Basic Tx function is to time multiplex a 16bit wide parallel loaded word into a f_{clock} x 20 serial ECL bit stream (nominally 200Mbit/sec). The Rx function is the inverse operation.

By using 2 G-link transceiver cards separated by transmission line , a point to point "virtual ribbon cable" is created.

The LSI chips hide much complexity from the user.

The Tx chip provides
- Parallel Word Input
- High speed clock multiplication
- Frame encoding
- Parallel to serial mux
- ECL ouputs

The Rx chip provides
- Clock recovery
- Data recovery
- Demux
- Frame decoding
- Frame synchronization
- Frame error detection
- ECL input

The DC balance of the line code is automatically maintained by the chipset.

In the M32 the G-link circuit is hardwired in a full duplex configuration,handling all the issues of link start-up ,maintenance and simple error detection required of a bidirectional system. An important repercussion of this is both directions of the digital link MUST be operational for the system to start-up.

Some simple options are configurable on board by S1- refer block diagram.

For normal operation 16bit mode is selected ,hence only D0 to D15 is used in operation. D0 is the antenna or central buffer I/O. The D0 line on the Rx chip has attached interface circuitry for the VLA style AB or CB. It removes the DC component from the waveform as well as provide the nominal 2vpp waveform required.

A great versatility of the G-link configuration is the asynchronous transport of signals from point to point when signal are derived from clocks of varied origins. A small jitter of $1/(2f_{clock})$ is added to each line D0-D15. For transfer of data in the kilohertz range the effects are negligible.

As the G-link chip sets are quite complex ,further operational details are available in the HP design document (5966-1183E 9/97)

Digital Fiber Optics Modem Card

The ECL compatible D_{out}, D_{in} signals from the G-link cards are only intended to drive short sections of copper cable. To utilize the 104km fiber to PT a fiber optic transceiver card is required with particular optical requirements needed for DWDM.

As the bi-directional link has to work on a single fiber ,each direction is confined to a specific optical channel of the 1550nm ITU grid. PT to the VLA at 1530nm , VLA to PT at 1535nm.

The laser transmitter is a directly modulated design . The laser diode submodule exhibiting low wavelength chirp characteristics for 2.5Gbit/sec in 2000ps/nm high dispersion fiber. For operation at 200Mbit/sec chirp effects can be ignored. As with many telecommunication DFB laser submodules the packages are common anode. Mechanical mounting and proper thermal dissipation fixes the case at 0vdc or chassis GND. In order to use this a negative bias is required on the cathode of the DFB. The MAX3667 SONET laser driver IC with Automatic Power Control is used with the usual IC Vcc made chassis GND and the IC gnd made –5vdc.

Two adjustments are required to set the fiber modem card. The modulation depth is set by Modset (50k pot) and adjusts the peak to peak power excursion with modulation. The average optical power is determined by the Apcset (50k pot). A combination of the two adjustments will maximize the distinction between an optical "1" and a optical "0" ,thus optimizing the extinction ratio.

Although modulation and bias current mirrors are available and scaled currents can be calculated by measuring the differential voltages (use isolated CRO as –5vdc is now "GND") across the modmon and biasmon resistors the more definitive adjustment uses the M32 in loopback.

By using the G-link card or G-link evaluation Tx card to supply a DC balanced bit stream to the fiber transceiver and looping the fiber Tx port back to the fiber Rx port via a 26dB attenuator or better still 104km test spool ,adjust the Modset and Apcset trimpots for optimum eyepattern opening and minimal jitter. In practice this will NOT correspond to maximum laser optical power due to MAX3667 limitations on modulation depth and heat dissipation. Optical output powers of 0dBm were found to provide best eyepattern results.

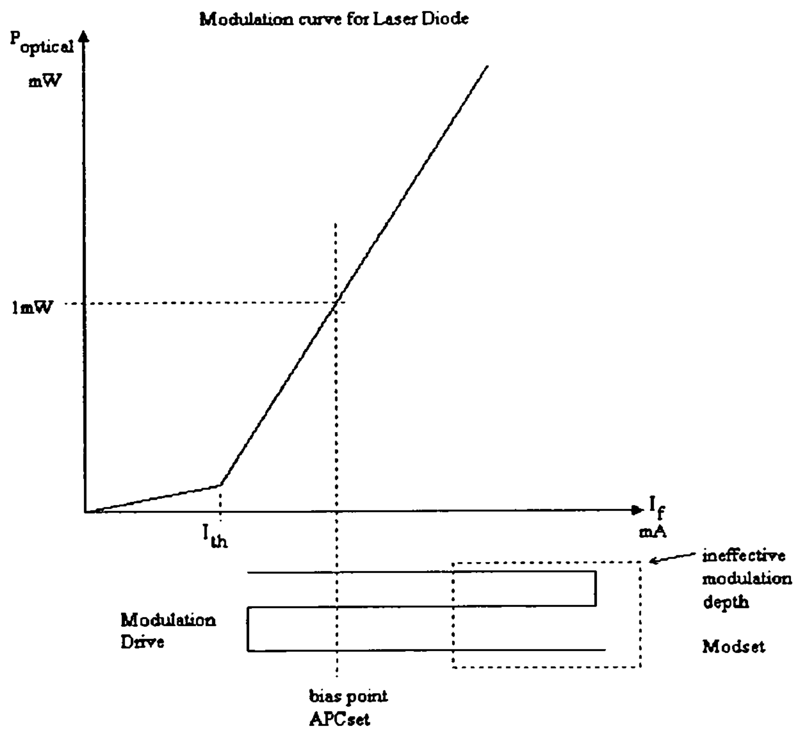
A crucial adjustment is that of laser wavelength. The optical wavelength must be set precisely within the transmission window of the fixed DWDM filter channel. Wavelength adjustment can only be effected by DFB temperature. Wavelength Electronics Corp PID control module HTC1500 provides exceptional thermal regulation. There are two adjustments on the HTC1500. The current limit should be set to 1amp ,use a 20k trim pot adjusted to 10k to simulate the DFB thermistor and 2R2 ohm resistor to simulate the Peltier cooler. Adjustment of the 10K above and below T_{set} (~1000mV) will either heat or cool (ie fwd or reverse the current in the 2R2 load).

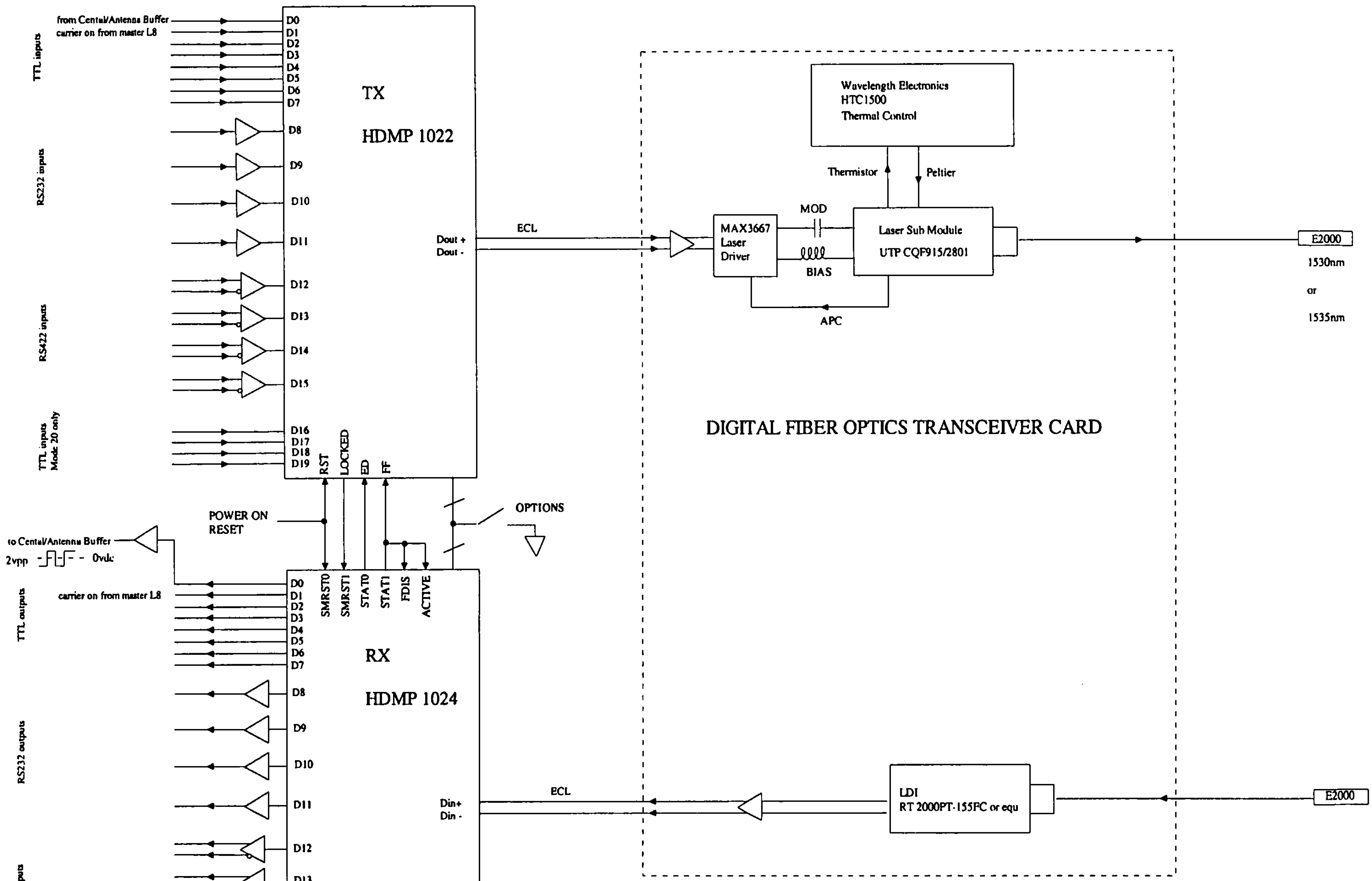
With the actual DFB installed the T_{set} monitor voltage should be 1000mV +/- 50mV. The $T_{monitor}$ should equal the T_{set} within minutes of power up. Note the DFB thermistor has a negative slope ,thus an increase in package temperature will correspond to decrease in $T_{monitor}$. $T_{monitor}$ should not drop below 950mV.

The optical Rx segment is essentially an ECL buffered submodule. The footprint corresponds to a SONET standard and are available from several vendors. The Rx module contains the PIN Rx diode ,AGC and limiting amplifier. Laser Diode Inc can supply a plug in replacements for 52 ,155 ,622 Mbit/sec modules.

In the current scheme the 155Mbit/sec unit works well at 200Mbit/sec data and an average light level of –38dBm. Typical receive light levels are –25dBm ,a healthy 13dB link margin assures reliable operation.

For operation at 622Mbit/sec a negative 5vdc is recommended on the PIN diode to enhance bandwidth.


Modulation curve for Laser Diode
P optical
mW
1mW
I f
mA
I th
ineffective
modulation
depth
Modset
Modulation
Drive
bias point
APCset



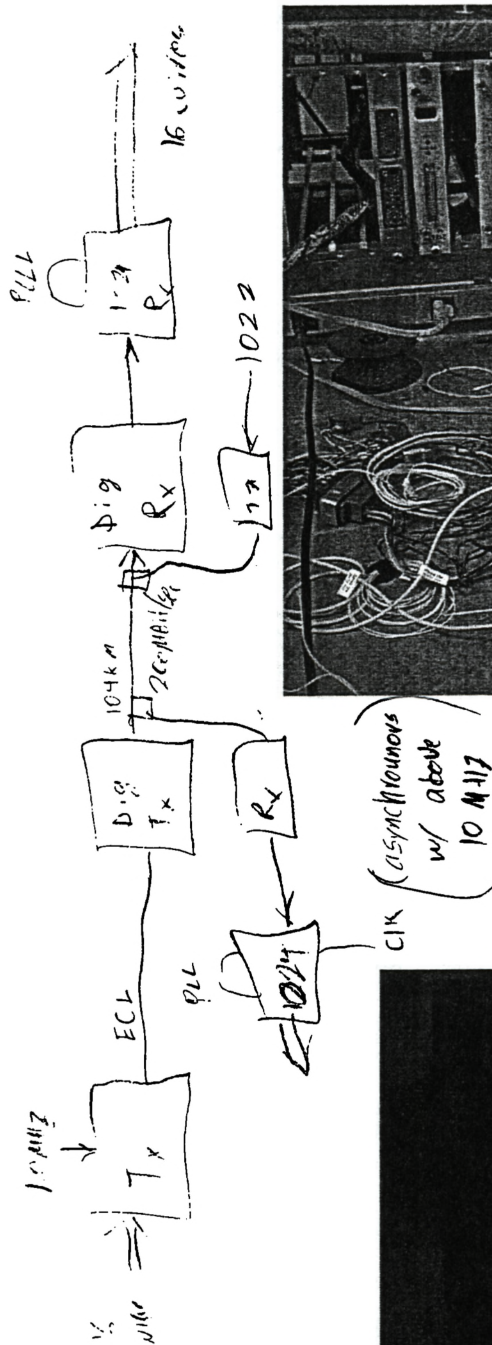
OPTIONS CONFIGURATION

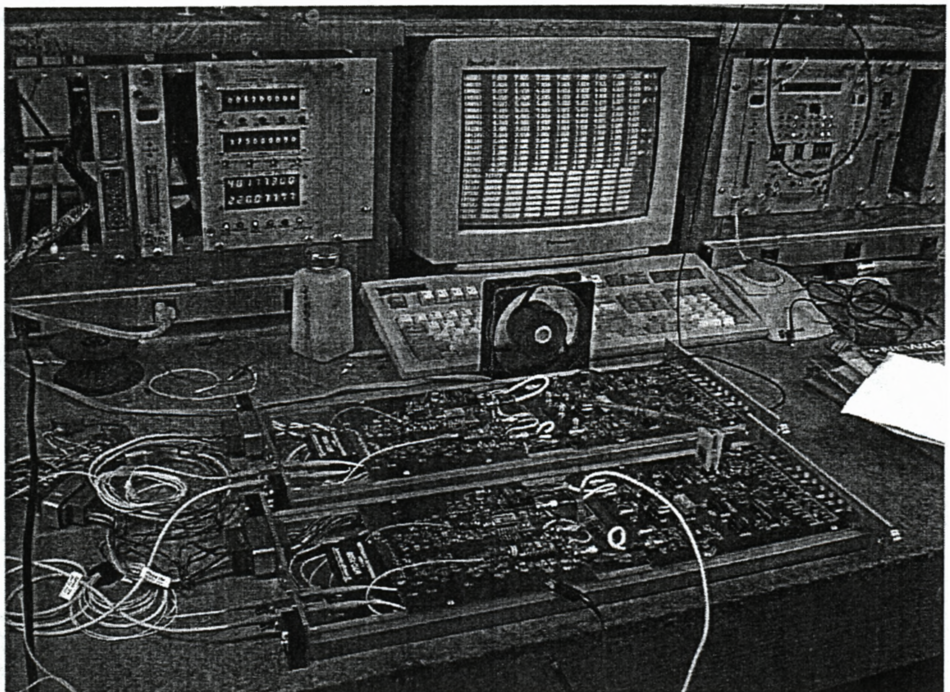
	SIGNAL	ON "0" OFF "1"	
S1 - 1	HCLKON	OFF	Divided high speed clock monitor output ("on" to pwr save)
S1 - 2	LOOPEN	ON	Local Loopback disabled
S1 - 3	DIV0	OFF	use 7.5 - 11.25 MHz XTAL
S1 - 4	DIV1	OFF	
S1 - 5	FLAGSEL	ON	Ignore extra flag bit
S1 - 6	M20SEL	ON	16 bit wide data bus selected
S1 - 7	EQEN	ON	Cable equalization Dout disabled
S1 - 8	[illegible]	OFF	[illegible]

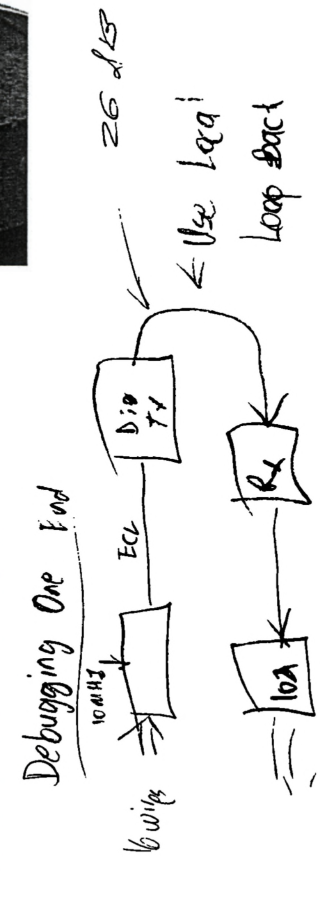
M32 BLOCK DIAGRAM

DIGITAL LINK TEST CONFIGURATION -NOV 99

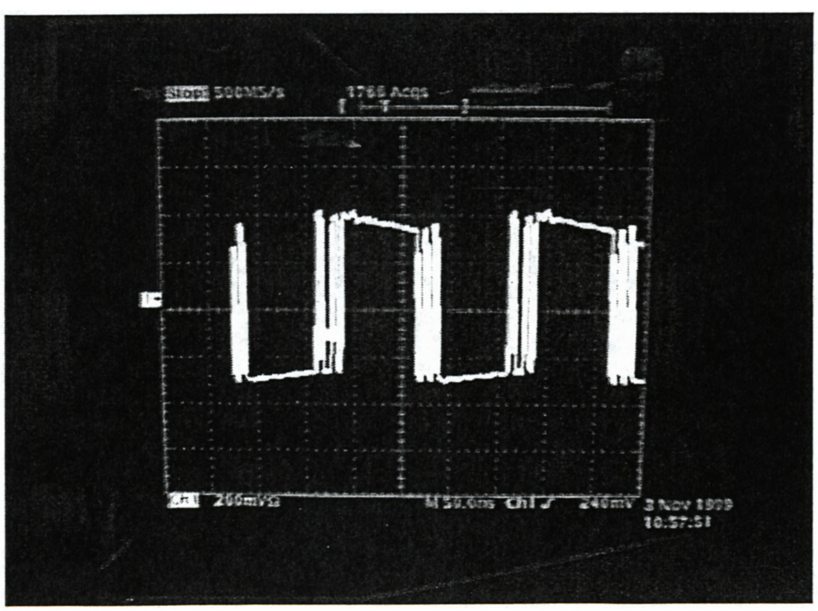
200MBit/sec





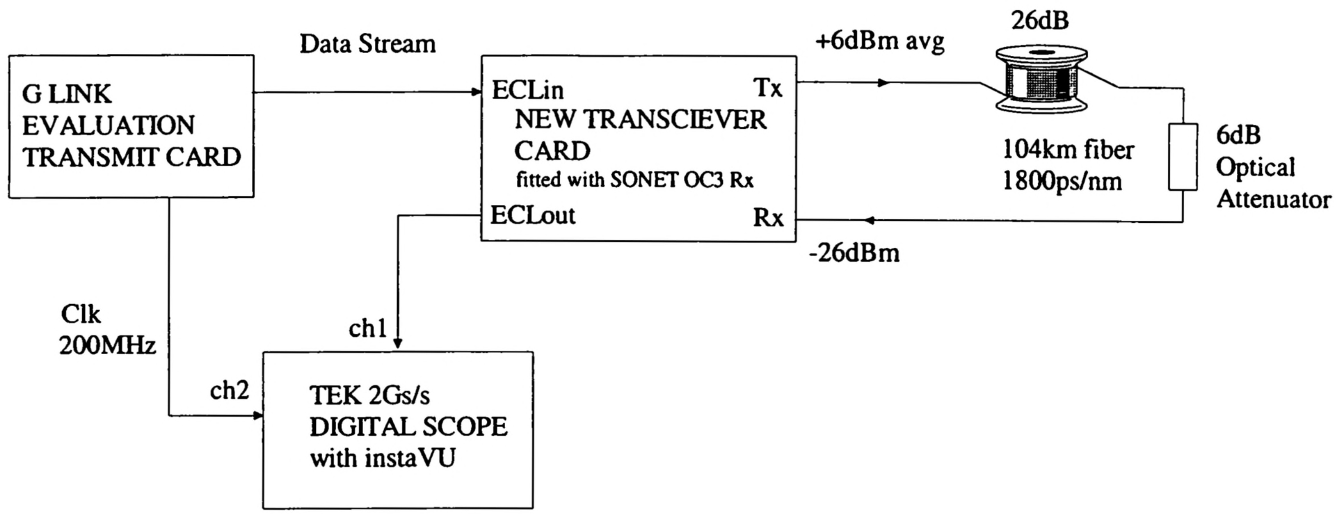


OUTPUT of FO TRANSCEIVER

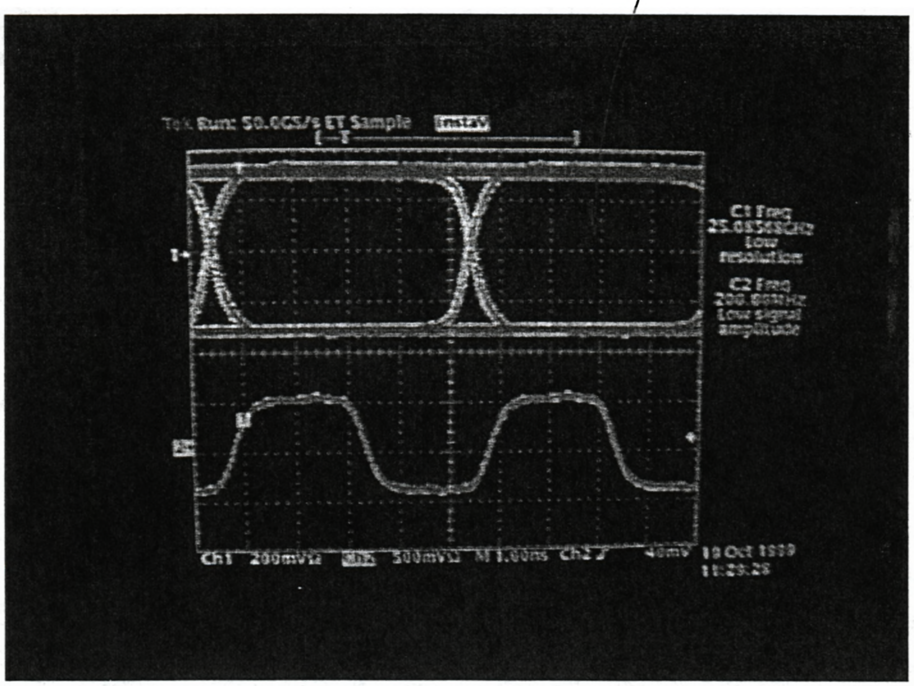


rjb 3 nov 99

REVISED DESIGN DIGITAL TRANSCIEVER CARD

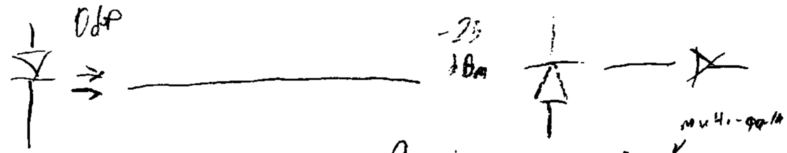


Want "no signal" in the middle.



EYE PATTERN ANALYSIS

rjb 19 Oct 99



S/N

N= thermal noise + shot noise + RIN + path interference

ANALYSIS PROGRAM
DIGITAL FIBER OPTIC LINK
USING DIRECT MODULATION TRANSIMPEDANCE DESIGN

Designed : Ron Beresford April 98

$N := 30$

$i := 0 .. N$

$L_i := i$ dB $\qquad Lf_i := 10^{-\left(\frac{L_i}{10}\right)}$

$P_{laser} := 1 \cdot 10^{-3}$ W $\qquad P_{laserdBm} := 10 \cdot \log\left(\frac{P_{laser}}{10^{-3}}\right)$ $\qquad Laser := \frac{P_{laser}}{10^{-3}}$ mW

$P_{idBm} := P_{laserdBm}$

$P_{in} := 10^{-3} \cdot 10^{\left(\frac{P_{idBm}}{10}\right)}$ W $\qquad$ Launched into SMF

$I_{dark} := 1 \cdot 10^{-9}$ A $\qquad e := 1.6 \cdot 10^{-19}$ C

$\eta := 0.80$ $\frac{A}{W}$

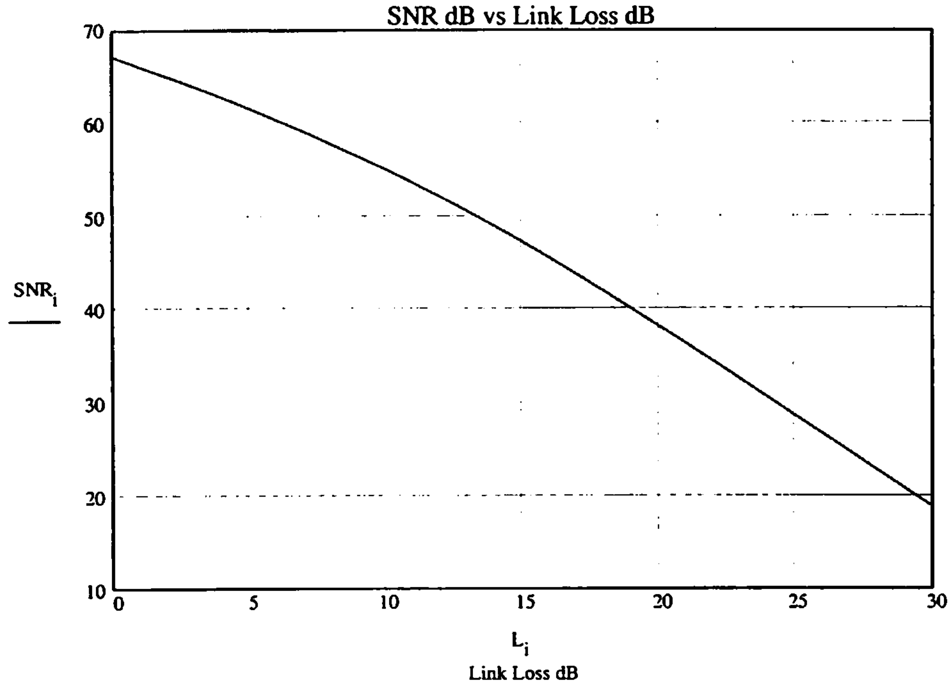
$Pout_i := Lf_i \cdot P_{in}$ W

$\Delta f := 200 \cdot 10^6$ Hz ← Bit Rate

$R_f := 100$ Ω

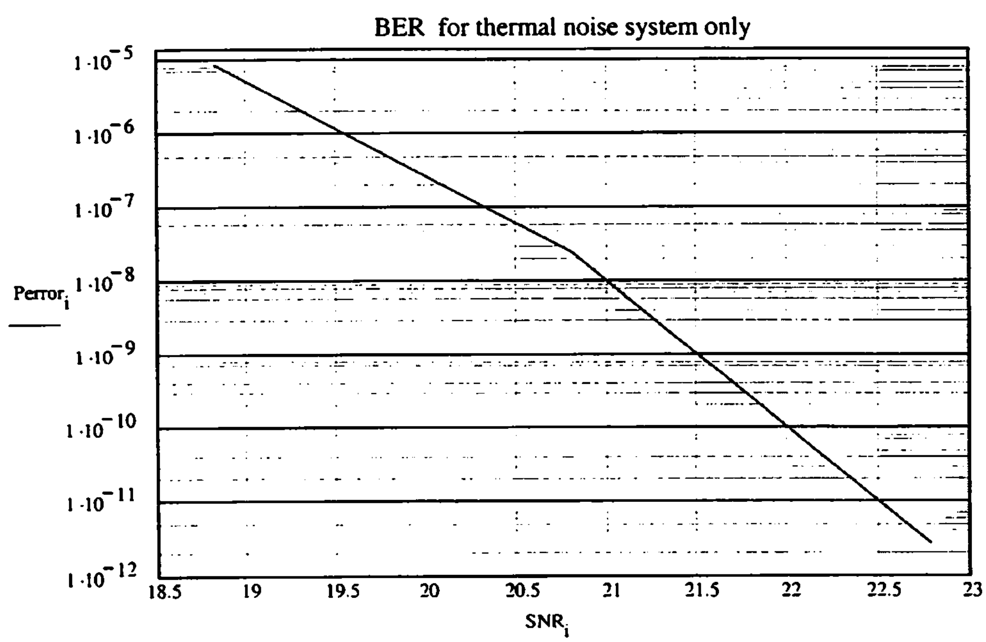
$k := 1.38 \cdot 10^{-23}$ $\frac{W}{K \cdot Hz}$ $\qquad T := 300$ K

$RIN_{laser} := -165$ $\frac{db}{Hz}$



$$Perror_i := \frac{1}{2} - \frac{1}{2} \cdot erf\left[0.354 \cdot \left(\sqrt{\frac{Signal_i}{N_{total_i}}}\right)\right]$$

for thermally noise limited system



'Link Noise Graph is missing.'

ASSESSMENT of DISPERSION

Spectral Width $N := 0 .. 100$ ie 0 to 0.1nm

$$v_N := \frac{N}{1000}$$ nm

$L := 0 .. 100$

Chromatic Dispersion $k_c := 20 \quad \frac{ps}{nm \cdot km}$ Dispersion constant

$$D_{ch_{N,L}} := k_c \cdot L \cdot v_N$$

Dispersion Plots missing

PMD $k_p := 0.1 \quad \frac{ps}{nm \cdot \sqrt{km}}$

$$D_{p_{N,L}} := k_p \cdot v_N \cdot \sqrt{L}$$

System Risetime

$$\Gamma_{d_{N,L}} := D_{ch_{N,L}} + D_{p_{N,L}}$$

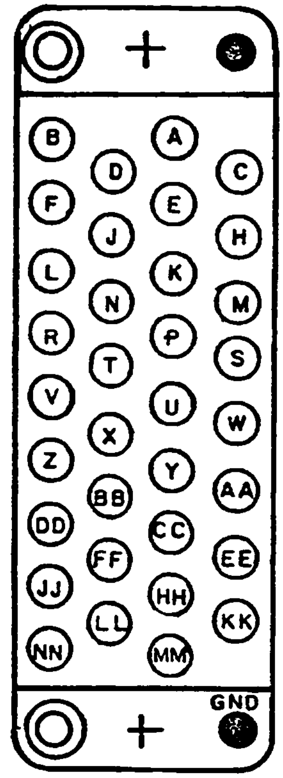
$f_r := 1 \cdot 10^9 Hz \qquad \Gamma_r := \frac{0.35}{f_r} \cdot 10^{12} \qquad \Gamma_r = 350$

$f_t := 1 \cdot 10^9 Hz \qquad \Gamma_t := \frac{0.35}{f_t} \cdot 10^{12}$

$$\Gamma_{sys_{N,L}} := \sqrt{\Gamma_r^2 + \Gamma_t^2 + \left(\Gamma_{d_{N,L}}\right)^2}$$ psecs

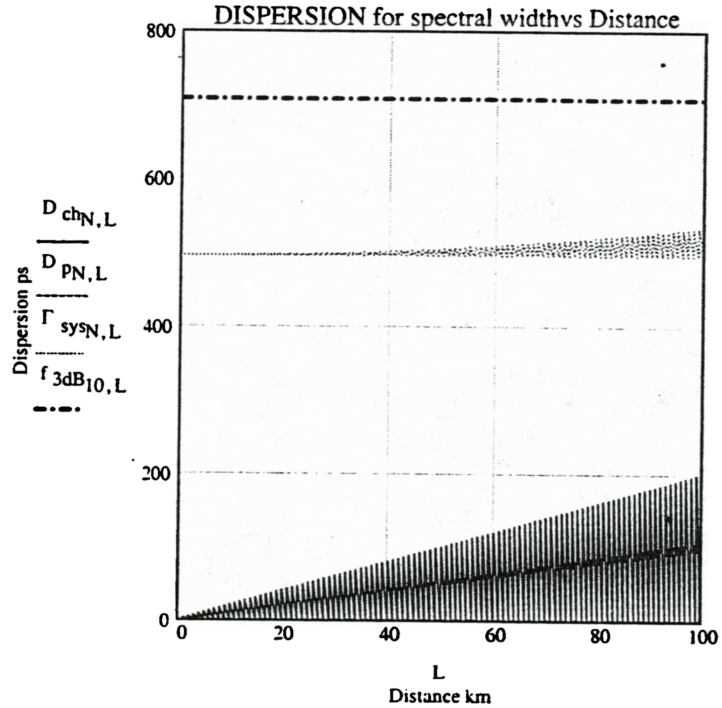
The 3dB Electrical BW $f_{3dB_{N,L}} := \frac{0.35}{\Gamma_{sys_{N,L}}} \cdot 10^6$ MHz

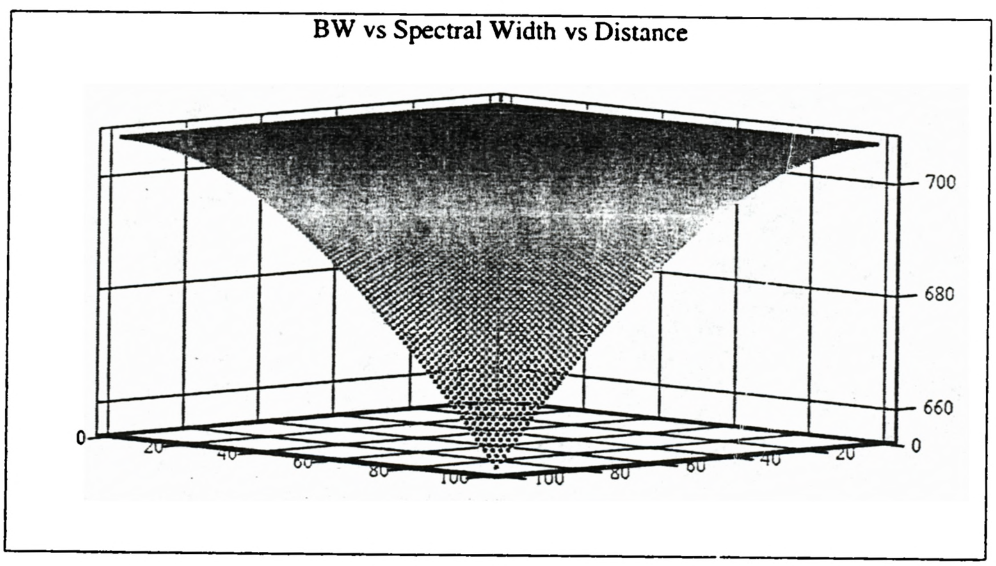
P.-TOWN G-LINK MODULE



P2 (REAR VIEW)

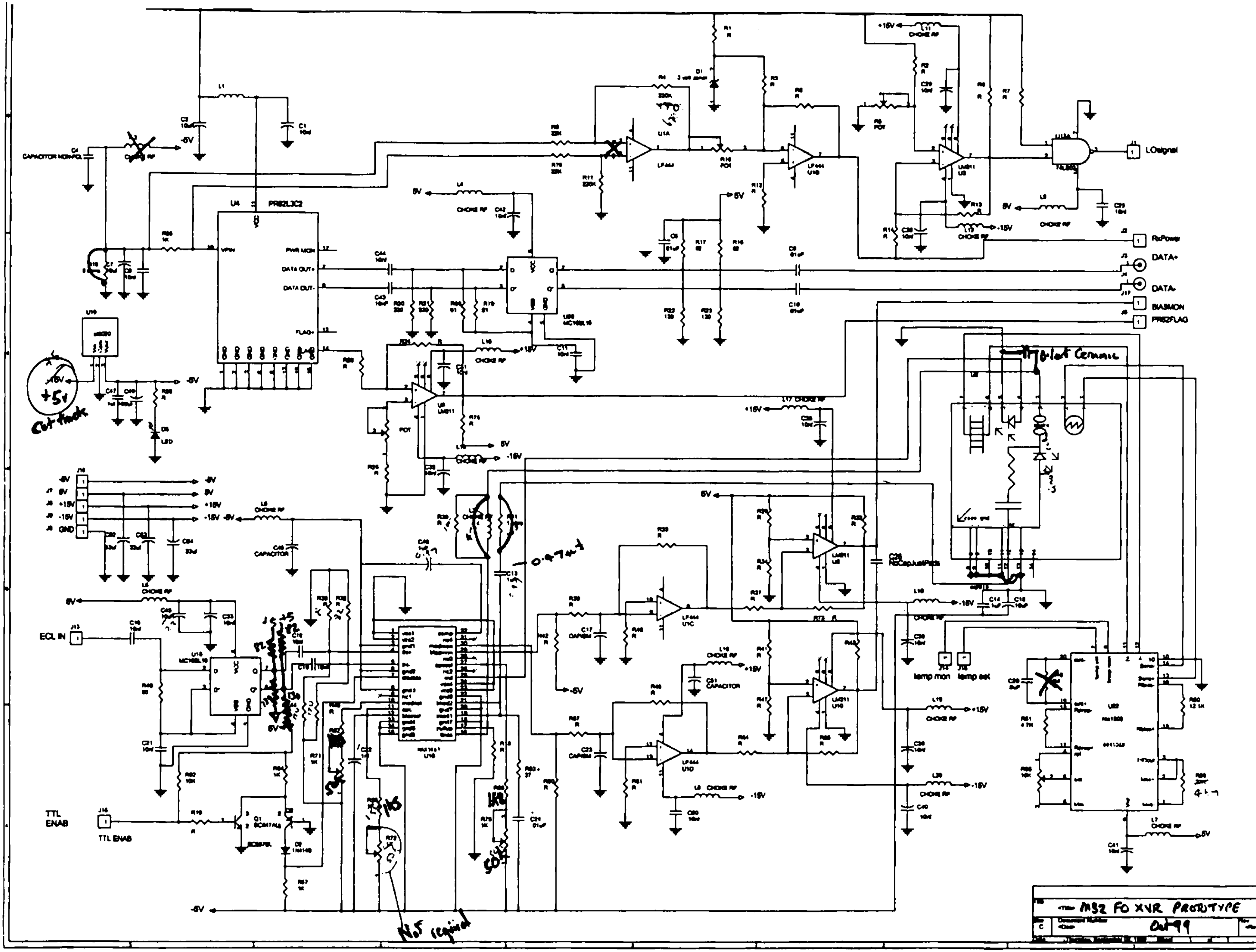
P2					
PIN	FUNCTION	WIRE COLOR	PIN	FUNCTION	WIRE COLOR
A	+15V	RED	V	CARRIER IN	GRAY (TW PR
B	GND	BLK	W		
C	+5V	ORANGE	X	CARRIER IN RET	BLK
D			Y		
E	-15V	YELLOW	Z	CARRIER OUT	GRAY (TW PR
F			AA		
H			BB	CARRIER OUT RET	BLK
J			CC		
K			DD		
L	BUFFER IN	GRAY (TW PR)	EE		
M			FF		
N	BUFFER IN RET	BLK	HH		
P			JJ		
R	BUFFER OUT	GRAY (TW PR)	KK		
S			LL		
T	BUFFER OUT RET	BLK	MM		
U			NN		





f_{3dB}

x axis is 0 to 0.1 nm spectral width (20 points)
y axix ix 0 to 100km
z axis is Bandwidth MHz



LOsignal
RxPower
DATA+
DATA-
BIASMON
PREZFLAG
PRE2L3C2
PWR MON
DATA OUT+
DATA OUT-
FLAG+
MC10EL16
LF444
LM311
CHOKE RF
CAPACITOR NON-POL
ECL IN
TTL ENAB
MC10EL16
BC847ALT
temp mon
temp set
Cut track
Not required
M32 FO XVR PROTOTYPE
Oct 99

RF FIBER OPTIC LINK

RF FIBER OPTIC LINK

The purpose of the RF fiber optic link is to transport the A 1325MHz ,B 1425MHz ,C 1575MHz and D 1675MHz IF's from Pie Town to the VLA. As each channel represents a noise bandwidth of 50MHz ,the combined bandwidth is 200MHz (280MHz including the 70MHz Bandwidth expansion). Additionally a 1200MHz is combined with the IF transmission to enable "one way phase" reckoning ,useful for gauging the site to site differential Maser frequency .

Preliminary design studies focused on a digital transmission scheme , essentially moving the samplers to PT and transporting the digitized IF's over the link to the VLA correlator.

Total Composite bite rate ~ *analog bandwidth* x *nyquist* x *quantizaton levels*
~ 200MHz x 2 x 4 bits
~ 1.6 Gbit/sec

With a digital transmission scheme ,as per SONET standards ,timing jitter of one tenth the bit period are acceptable. At 1.6 Gbit/sec aberrations of 60ps are tolerable. A "snapshot" of the IF's are made and transported across the link uncorrupted or with minimal BER. For radio astronomical applications the BER can be as poor as 1×10^{-5} . For comparisons sake a telecommunication link needs to be better than 1×10^{-9} .

Unfortunately the use of a digital transmission system for IF transfer would present a quandary of invasive interface problems for the existing VLA architecture.

Additionally there is still a need for analog systems in the PT equipment. To maintain maximum compatibility with all receiving bands common to the VLA and PT both USB and LSB conversion ability is required. Fringe rotation is required unless PT is made the center of the array, which is considered undesirable. Analog processes that would need to be done somewhere. In addition the use of standard VLA waveguide channels 1325 to 1675MHz with the use of VLA LO modules offers significant reuse of VLA control software.

Conceptually there appeared no reason why an Analog IF transmission scheme wouldn't work provided particular attention is paid to Dynamic Range DR , Signal to Noise SNR and RF phase.

Ease of interface and familiarity with the existing VLA by using RF transmission essentially trades the less stringent (60 ps) time domain tolerances of digital implementation for very tight frequency domain characteristics , eg 1 ° RF phase error at 1675MHz or 1.7ps. Or to paraphrase the RF link quality would need to be more than an order of magnitude better than a like digital link.

Direct and External Modulation

Direct modulation is inherently inefficient and the effect of laser wavelength chirping at 1GHz/mA (1GHz~0.01nm) of bias change would lead to an unusable system when multiplied by the 1800ps/nm fiber dispersion over 104km. Unwanted phase irregularities of many hundreds of degrees could be expected.

By externally modulating an ultra stable CW laser with a MZ modulator wavelength chirping is eliminated. In addition ,unlike a direct modulation scheme ,increasing the CW laser power will reduce the link noise figure.

Dynamic Range Specification

The dynamic range of phased arrays for radio astronomy is often a discussion point. Radio astronomy signals are defined as having white noise characteristics and final system signal to noise ratios of 20dB are adequate for digitization and good astronomy. Unfortunately the increased demand by the commercial for electromagnetic spectrum has led to large amplitude narrow band interfering signals in many radio

Practical Limitations to Link Dynamic Range

Practical limitations in obtaining a high dynamic range externally modulated RF link mainly revolves around maximizing the highest possible optical levels in the link ,ie maximizing light at the photodetector. It should be remembered that increasing levels in the optical domain by 1dB will increase signal levels in the RF domain by 2dB as predicated by the photodiode receiver square law, so the effects are significant.

The first and foremost step in maximizing the link dynamic range was to minimize the optical loss between PT and the VLA. A point to point 104km dark fiber connection was established by fusion splicing all intermediate junctions. As a result a loss of 21.7dB at the analog laser wavelength of ~1554nm was achieved. Some further reduction (perhaps a dB) may have been achieved by redoing some of the WNMT interconnects ,but this was not pursued for practical reasons. The total point to point loss of the best fiber at this wavelength including optical multiplexing networks was 25.7dB.

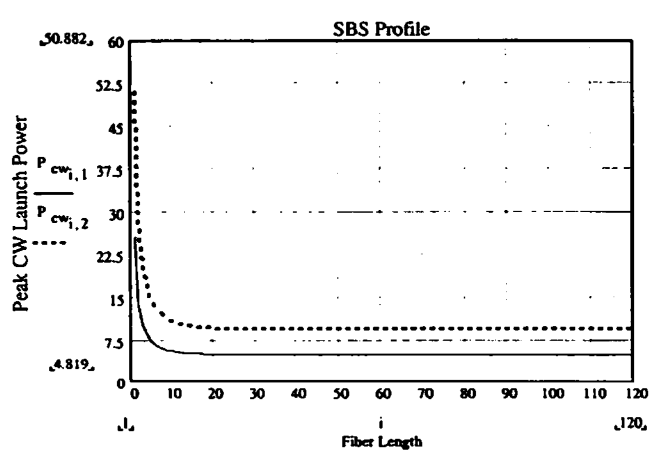
Photodetector efficiency for InGas PIN diodes is quite high in the 1550nm band with a responsivity of 0.8mA/mW and is inherently a very linear process. The use of Avalanche photodiodes was considered in to increase the SNR by approximately 4-6dB . This is however a non-linear process inappropriate for the broadband IF transmission and more suited for digital only or single tone RF demodulation. In the final implementation a received optical power of –15.6dBm was obtained at the PIN diode.

CAD modeling revealed that there is a one for one relation ship between the noise figure of the amplifier immediately proceeding the PIN detector and the noise floor of the link. Hence fitting a quality 2dB NF preamplifier in place of a 4dB NF dropped the link noise floor 2dB.

The PIN diode typically has an output impedance of 500 ohm. The input impedance of the proceeding preamplifier is 50 ohm. This mismatch presents a significant inefficiency . For RF in the 1.2 – 1.8GHz range construction of a low loss broadband transformer was seen as a dubious pursuit given project deadlines. Vector network analysis of the final "mismatched" configuration revealed excellent 50MHz passbands for VLA channels A,B,C,D. Resistive matching was not required.

In long or high loss fiber optic links the link noise floor as referred to the input of the link (modulator input) is determined mainly from the thermal noise of the system. Modeling did however reveal that laser RIN noise would also contribute but to a lesser degree. The DFB lasers deployed in the final implementation exhibit very low RIN noise at better than –160dB/Hz for the RF frequencies used.

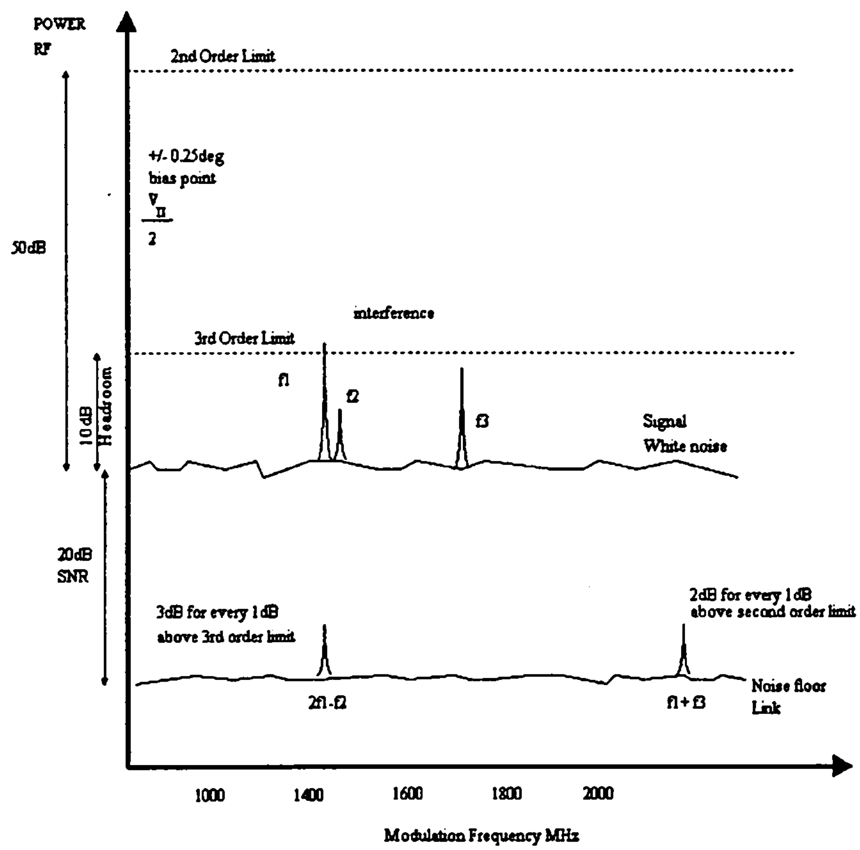
Perhaps the most significant issue requiring attention was the effects of Stimulated Brillouin Scatter (SBS). This is a non linear effect with narrow line width high power optical carriers and long fibers. The forward travelling photonic wave interacts with the glass molecule phonic vibrations. A backward travelling CW line offset by 11GHz is generated. Optical power is wasted in this process decreasing the SNR of the desired 1550nm forward wave. In practice without proper attention to SBS launch powers of only 4mW are possible into standard aperture fiber ,increasing beyond this SBS threshold can actually decrease the system SNR.



astronomy bands or in closely adjacent spectrum. In the future significant advances will need to be made in interference mitigation.

On this premise the PT Link Dynamic Range specification should be made as large as reasonably achievable. It turns out that a third order intercept based dynamic range of 30dB is a practically achievable goal. This leaves a moderate 10dB dynamic headroom above the signal given a SNR of 20dB.

DYNAMIC RANGE OVERVIEW



It is clear that out of band interference CW signals can "mix" in the non-linearity of the fiber link and generate in band spectral components. The 2[nd] order suppression is determined by the MZ modulator bias point and usually a concern with very wideband transmission. As the PT link is a suboctave system with signals in the range of 1200MHz to 1800MHz it is only the 3[rd] order distortion products that are relevant. This is calculable from the third order intercept point of the MZ modulator and other devices cascaded in the link.

RF Phase

The two main considerations for knowledge of link delay (phase) are for reckoning of the 1200MHz tone derived from the PT maser to correct for differences in LO frequency between sites ,that is a correction to the sky frequency and secondly to correct for aberrations in phase of the IF signals at Ch A,B,C,D. There are several mechanisms responsible for phase anomalies on the PT Link.

Perhaps the most definitive way of knowing the relative phase of PT with respect to the VLA is to use radio astronomical calibration. This can produce very satisfactory results provided the atmospheric seeing is the same for both sites. This may not hold ,particularly at Q band sky frequencies and poor weather.

Analog fiber optic links have intrinsic physical properties which if unaccounted can compromise the data quality.

[redacted] is the result of crosstalk between orthogonal voltage vectors Ex Ey In single mode fiber as the light signal propagates down the waveguide. In effect only a single polarization is launched into the fiber but the orthogonal "rays" have taken different paths ,encountered different refractive index (birefringence) and emerged from the fiber receive end with a differential group delay. This is a relatively slow effect (scale of minutes),excited by mechanical stress on the fiber length and changes in fiber temperature.

The PT link 104km fiber has a quoted PMD of 0.5ps /km$^{1/2}$ or 5.1ps rms . Given the highest frequency in the link is 1800MHz ,period 556ps , a $\phi_{rms} = 3.3°$ can be expected. Although for concatenated lengths of fiber as for PT there is a statistical improvement factor .

[redacted] is another effect for consideration. Standard jacketed single mode fiber exhibits a 10ppm /°C thermal coefficient of expansion. With large above ground swings in temperature on short segments of cable and small underground swings in temperature on long segments of cable the total phase variation with time is calculated at 0.025° phase/sec at 1200MHz. Actual round trip phase measurement at 1200MHz revealed 0.006° phase /sec. This assumes fiber reciprocity in a two fiber test scheme.

Round Trip Phase on a single long fiber line is made difficult by the Rayleigh Backscatter Effect which in practice limits the ORL to 33dB ,or approximately 1° of phase error at what ever frequency (1200MHz) is distributed. Hence using a 1200MHz signal to calibrate the phase between sites could yield errors of 30° rms at Q band. Increasing the RT LO signal to noise would entail the use of separate lasers of different wavelengths at each end of the link. Different wavelength lasers will generate huge errors in a system with chromatic dispersion as high as 1800ps/nm.

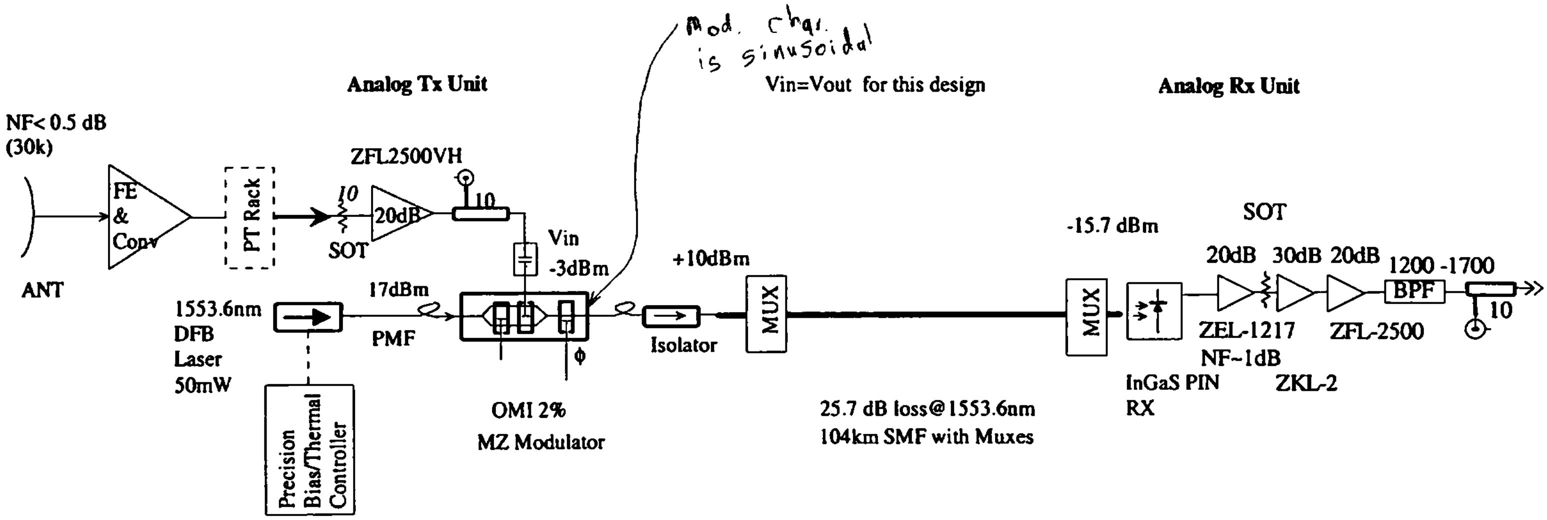
[redacted] are contribute to a change in signal delay and hence phase .With careful design these effects are reduced to minimal amounts over typical calibrator intervals of 30 minutes. Deliberate spreading of the laser CW line to overcome SBS limitations introduces a 1° rms phase error at audio rates.

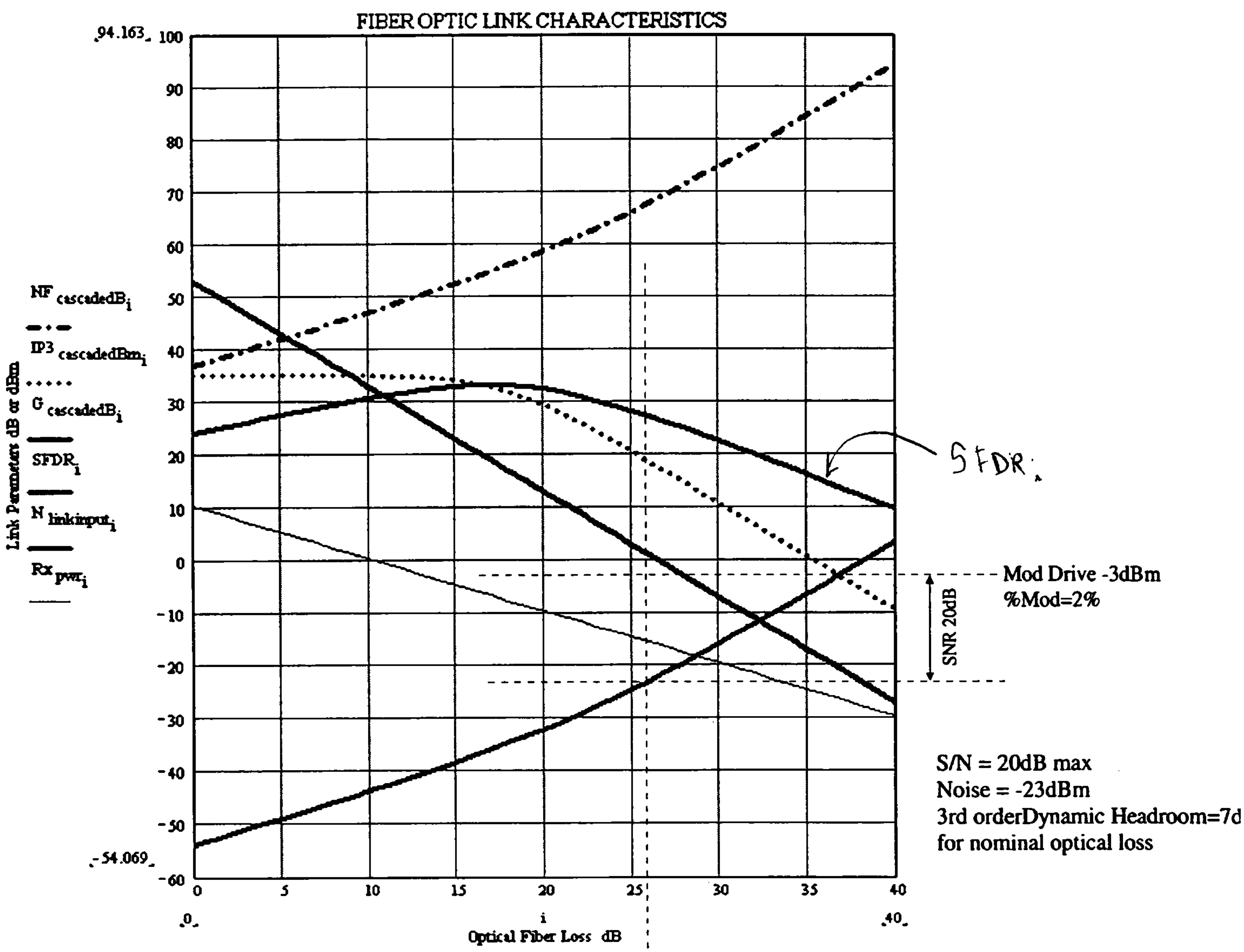
[redacted] are known to exist. For the PT to VLA this could be as high as 1 part in 10^{13} This will generate a differential frequency of around 1µHz at 5MHz. At Q band (45GHz) the difference in Sky LO's is 9mHz or 0.056°/sec.

Analysis will continue to determine how best to use the 1200MHz tone for the site to site LO coherence. Perhaps a combination of 1200MHz tone reckoning and astronomical phase calibration will yield true LO phase reckoning.

G= F_laser^2

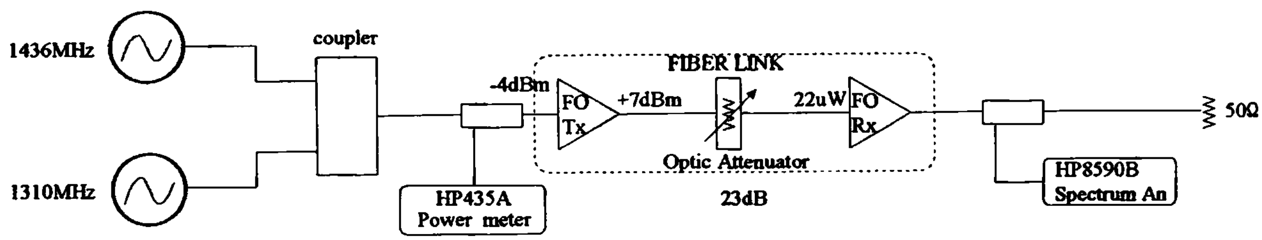
PT LINK ANALOG FIBER OPTIC LINK USING EXTERNAL MODULATION





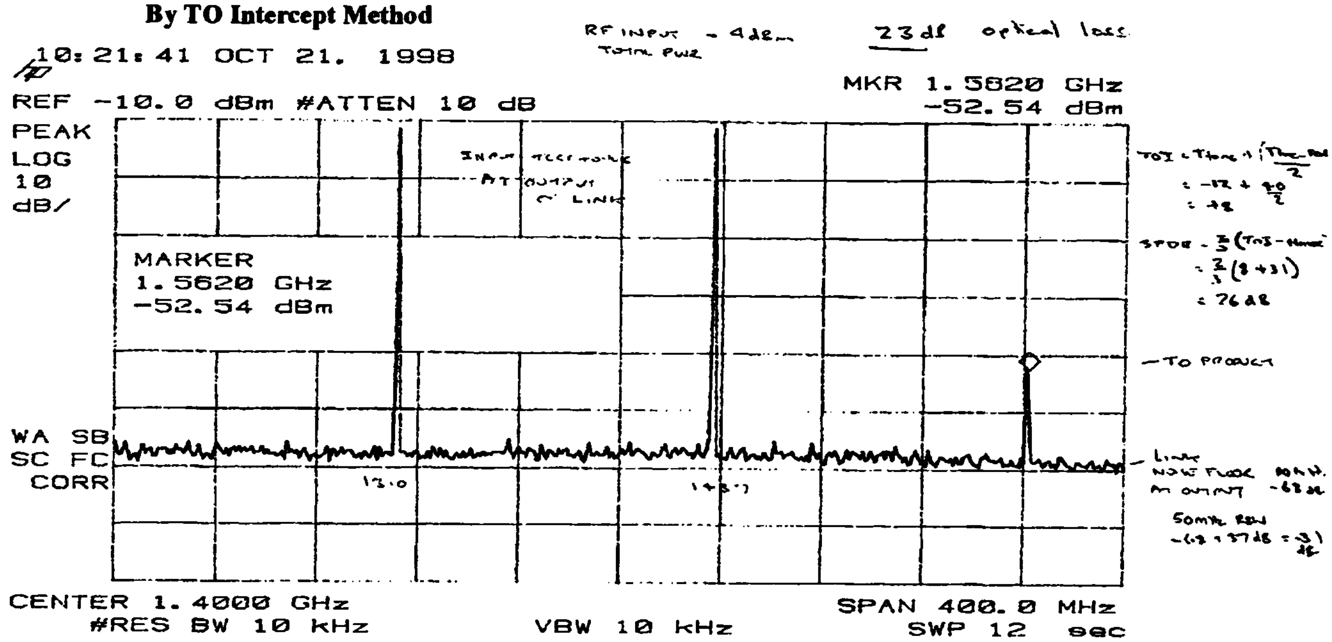
Nominal 25.7dB loss

SPURIOUS FREE DYNAMIC RANGE MEASUREMENTS

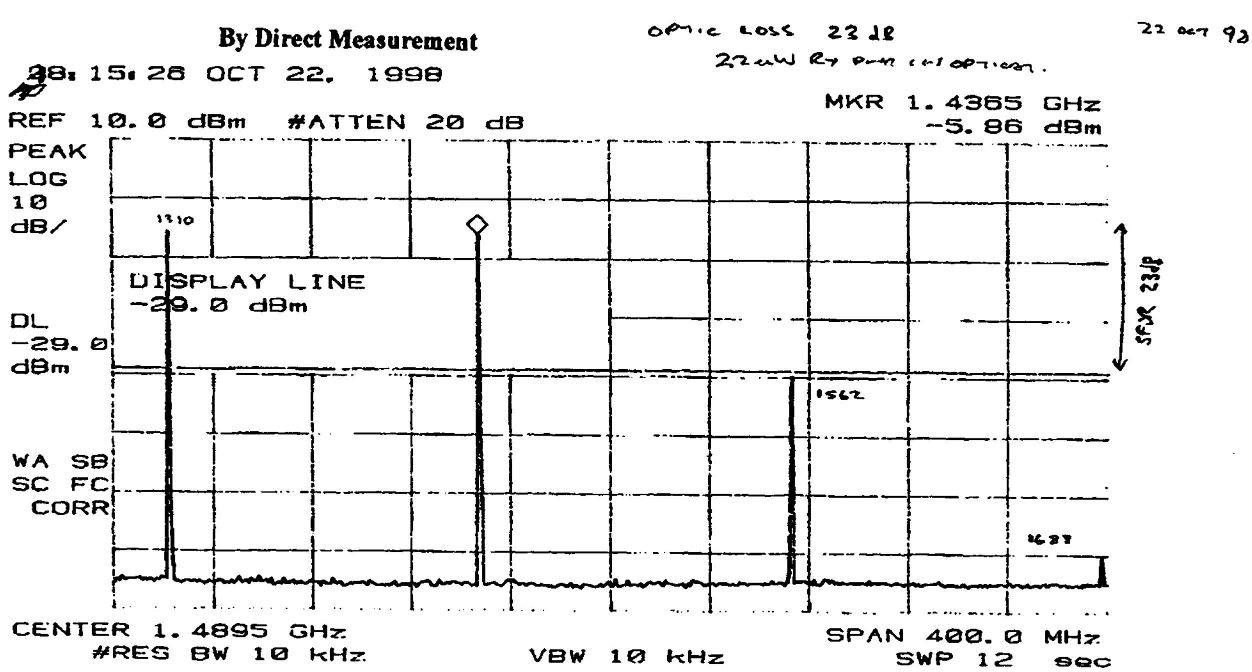


$$TOI = Ttone + \frac{Ttone - TOproduct}{2} \qquad SFDR = \frac{2}{3}\,(TOI - Noise)$$

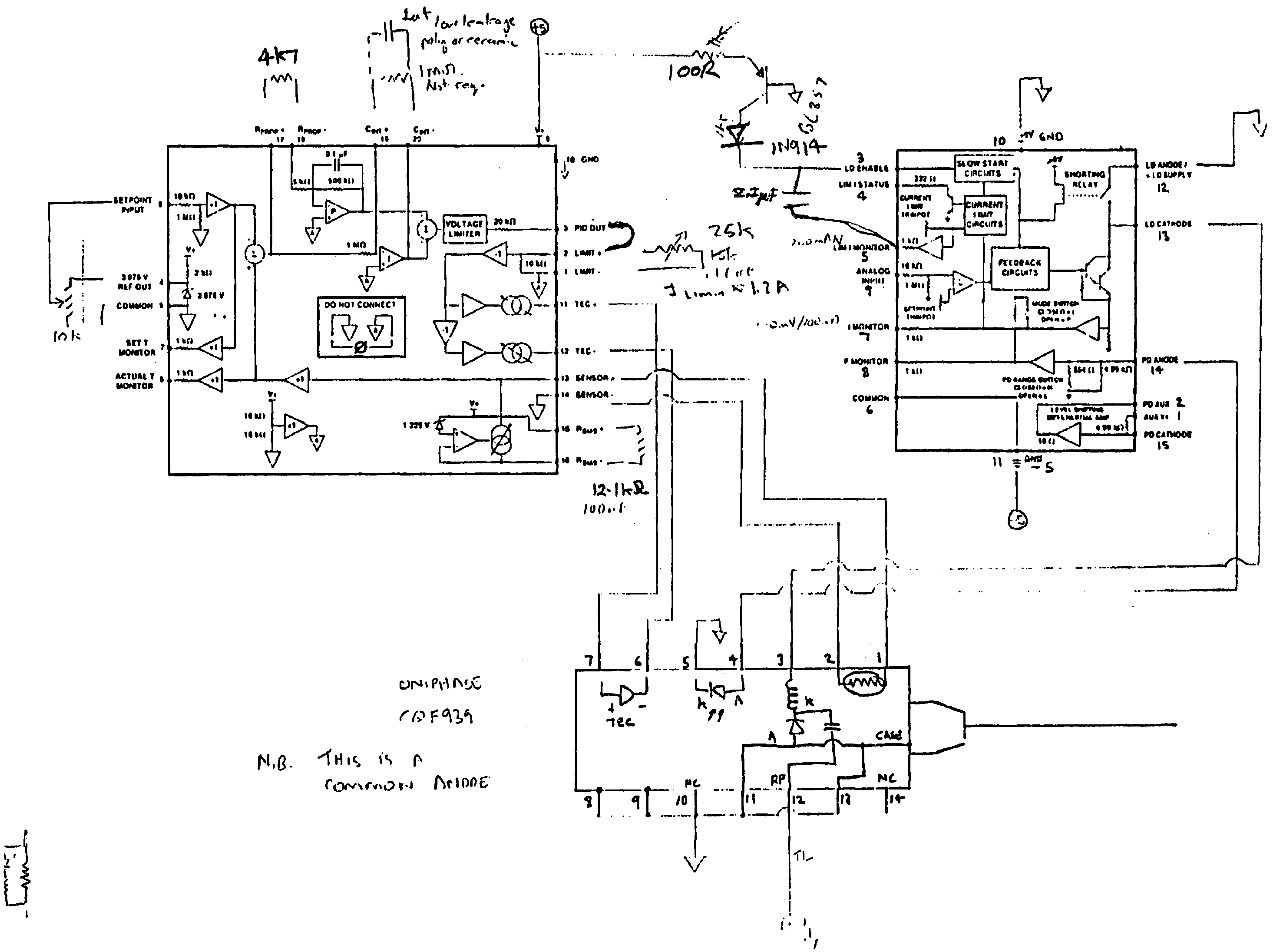
By TO Intercept Method



By Direct Measurement

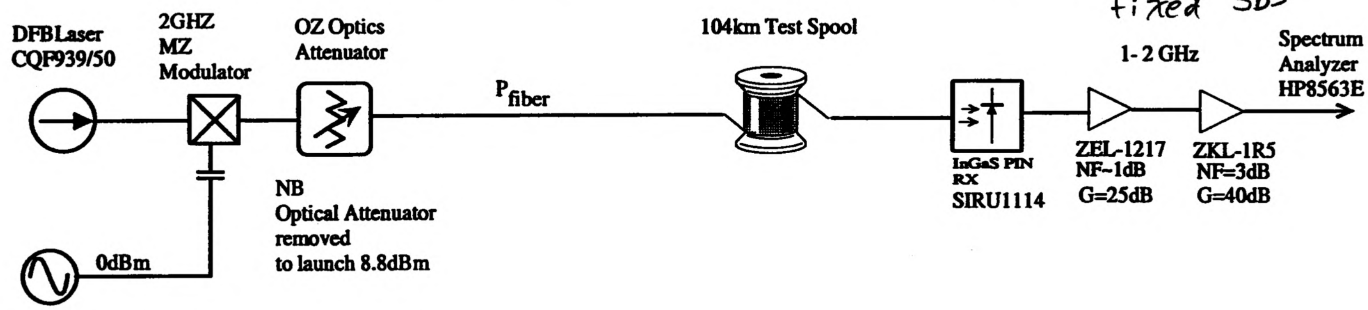


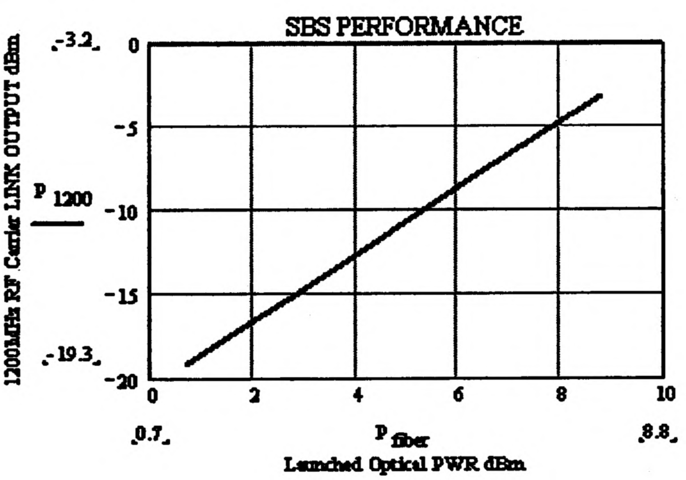
PRECISION DFB LASER CO...RO...

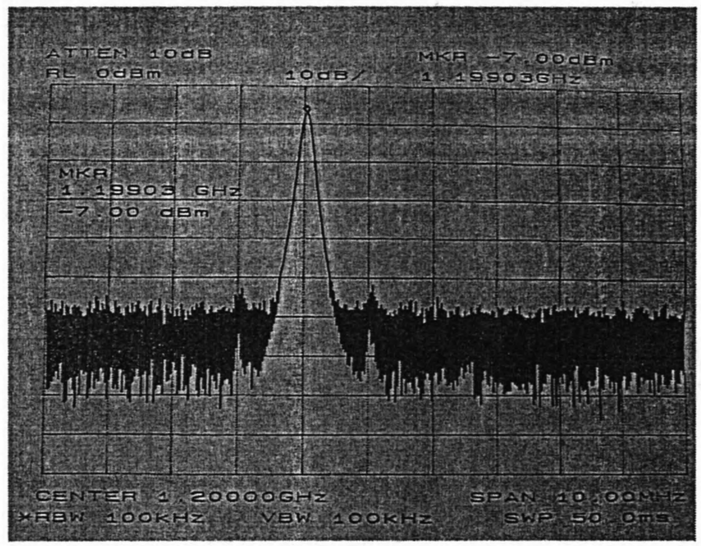


STIMULATED BRILLOUIN BACKSCATTER MEASUREMENTS

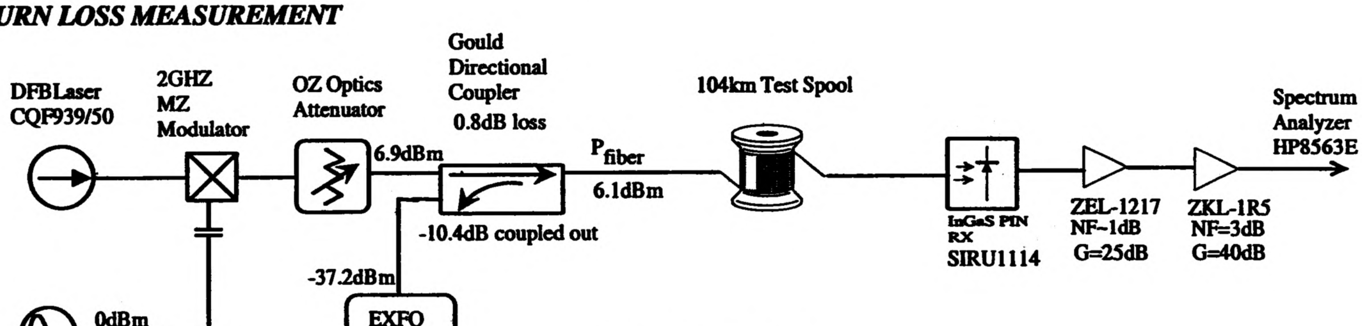
2. *MODULATED OPTICAL SIGNAL* — Test for SBS / not found F.M'ing of Bias control network fixed SBS







3. *RETURN LOSS MEASUREMENT*

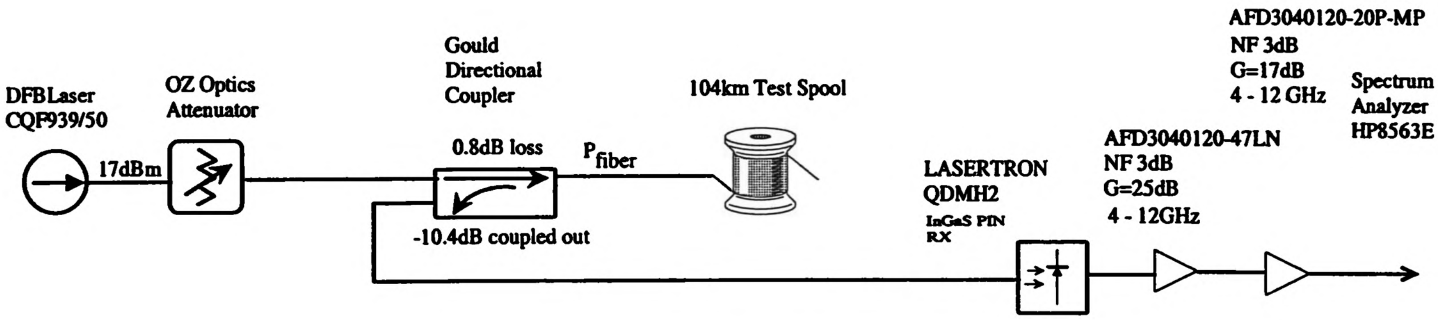


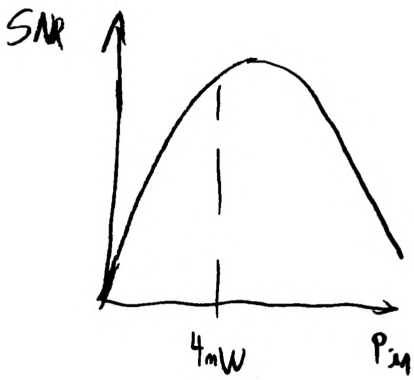
ORL = 6.1- (-37.2 +10.4)
= 32.9 dB

rjb 22 sept 99

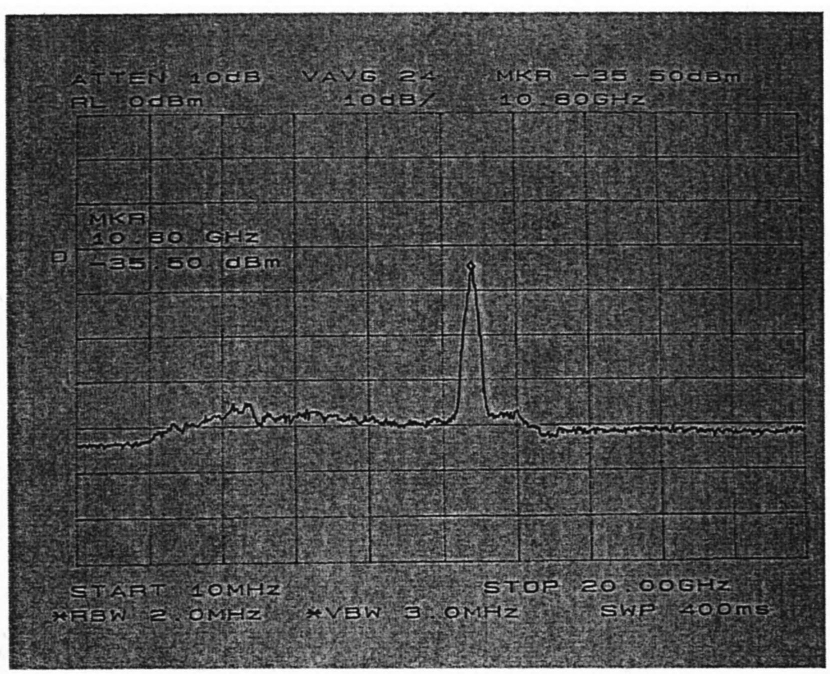
STIMULATED BRILLOUIN BACKSCATTER MEASUREMENTS

1. UNMODULATED OPTICAL SIGNAL



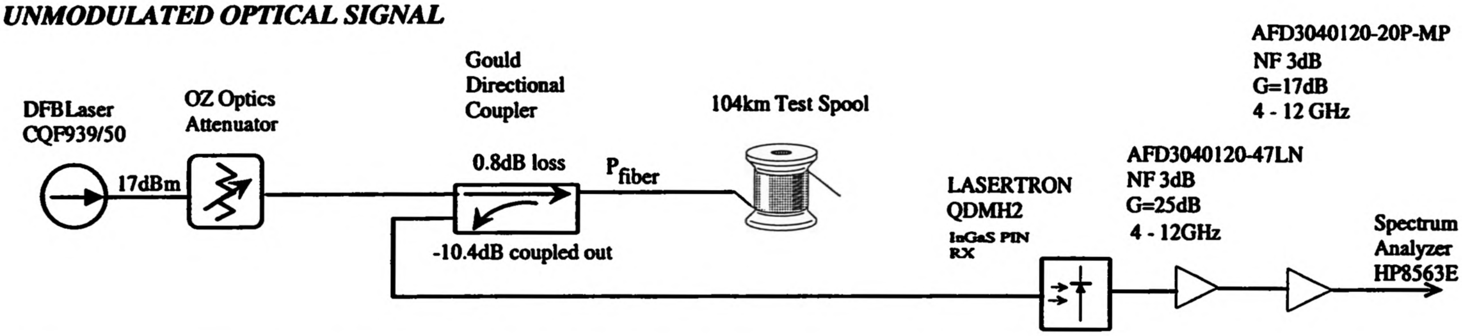


P_{fiber} dBm	SBS Peak 10.8GHz dBm
15.5 att out of path	-35.5
14.1	-44
13.1	-52
12.1	-60
11.1	-66
10.1	<-68 Link Noise Floor



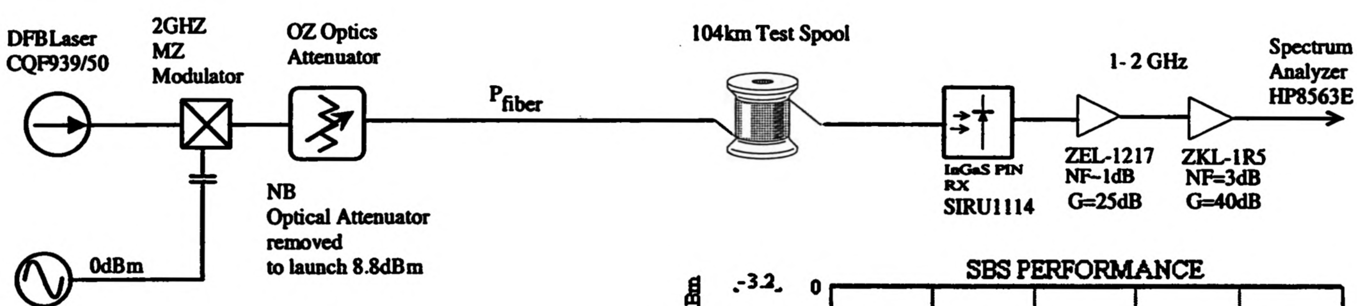
STIMULATED BRILLOUIN BACKSCATTER MEASUREMENTS

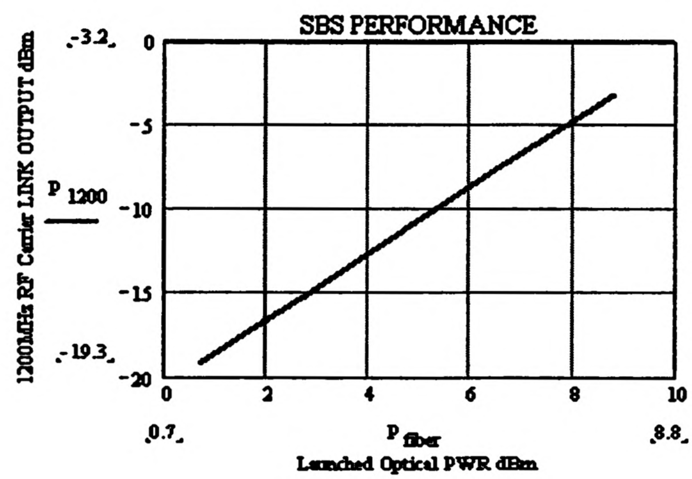
1. UNMODULATED OPTICAL SIGNAL



P_{fiber} dBm	SBS Peak 10.8GHz dBm
15.5 att out of path	-35.5
14.1	-44
13.1	-52
12.1	-60
11.1	-66
10.1	<-68 Link Noise Floor

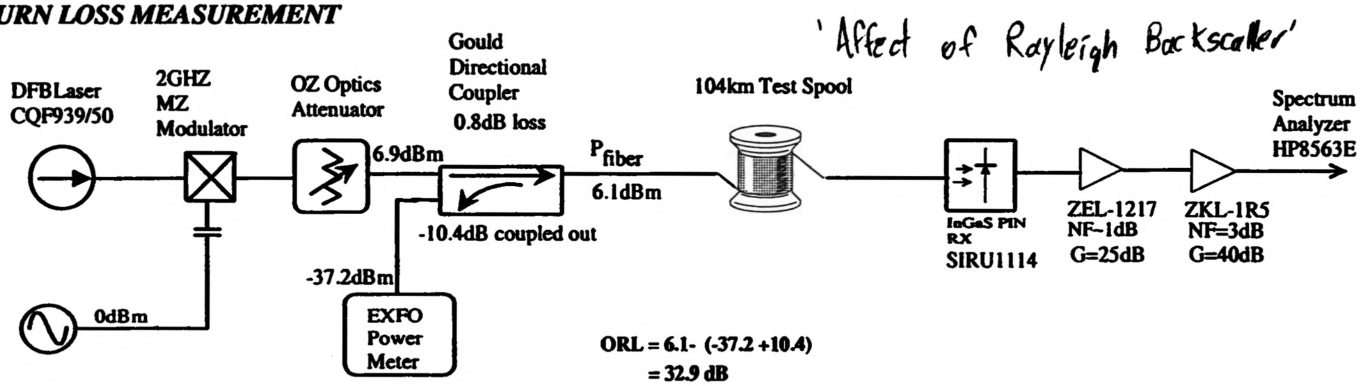
2. MODULATED OPTICAL SIGNAL





3. RETURN LOSS MEASUREMENT

'Affect of Rayleigh Backscatter'

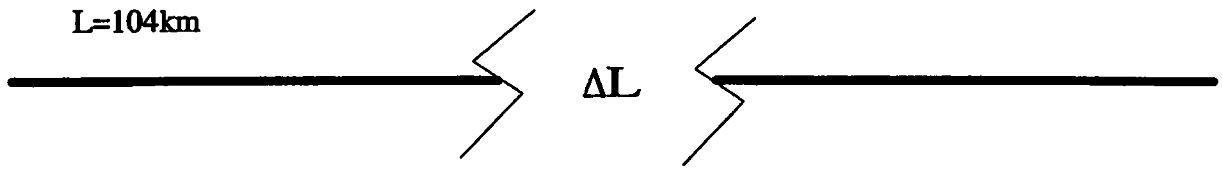


ORL = 6.1- (-37.2 +10.4)
= 32.9 dB

rjb 22 sept 99

TRANSMISSION LINE CHANGES vs TEMPERATURE

rjb 29 Jan99



$\frac{\Delta L}{\Delta T}$ = 10ppm/ °C coefficient of thermal expansion for Standard Singlemode fiber.

Lets assume the cable is buried at a depth of 1 meter where the diurnal ΔT is less than 0.1 °C / day or 0.004 °C / Hr

Lets assume that in 104kms the cable exits the ground for add/drop and splicing etc ,say 10 locations. At each of these locations 10m of cable is exposed to a ΔT =20 °C / Hr

$$\Delta L_{total} = \Delta L_{buried} + \Delta L_{exposed} \quad \text{per hour}$$

$= 104{,}000\text{m} \times 10\text{ppm} \times 0.004 \quad + \quad 10 \times 20\text{ m} \times 10\text{ppm} \times 20$

$= 0.004\text{m} + 0.04\text{m}$ per hour

$= 44\text{mm/Hr}$

$= 0.012\text{mm/sec}$

$$\lambda_{1200MHZ} = \frac{C}{f\, n_{fiber}}$$

$$= \frac{3 \times 10^8}{1200 \times 10^6 \times 1.45}$$

$$= 0.172 \text{ m}$$

$$\frac{\Delta \Phi}{\Delta t} = \frac{\Delta L_{total}}{\lambda_{1200MHZ}} \times 360°$$

$$= \frac{0.012}{172} \times 360$$

$$= 0.025\ ^{\circ}/\text{sec}$$

POTENTIAL SOURCES OF ROUND TRIP PHASE ERROR

LASER FREQUENCY AGING

nominal λ= 1554nm D= 18ps /nm/km

for 208km PT return length D = 3.74ns/nm

for $\delta\phi = 0.006^{o}$/sec $\delta\tau = 0.014$ps /sec

hence $\delta\lambda$= 3.74×10^{-6} nm /sec

= 0.32 nm/day or 118nm /yr

Normal aging is 100GHz/yr ie 1nm/yr
or 1620degrees /year at 1200MHz
or 4.4 degrees phase/day ....so this is UNLIKELY!

LASER THERMAL DRIFT

The Laser is believed to be stable to 0.001^{o} C

With Laser Temp dependence of 0.1 nm/ C

The error in λ will be 0.0001nm or 0.1 picometer

The error in delay will be 0.374 ps or $\Delta\phi$= 0.16 degrees at 1200MHz

Even if the Thermal Stability were 10x worse it would only account for 1.6 degrees of phase. In addition it is unlikely the laser thermal drift would continue monotonically in one direction......................................UNLIKELY

FIBER DISPERSION WITH TEMPERATURE

Generally - $\frac{\Delta D(T)}{\Delta\lambda}$ ~0.02nm /C for SMF

Thus if D = 3.74ns/nm

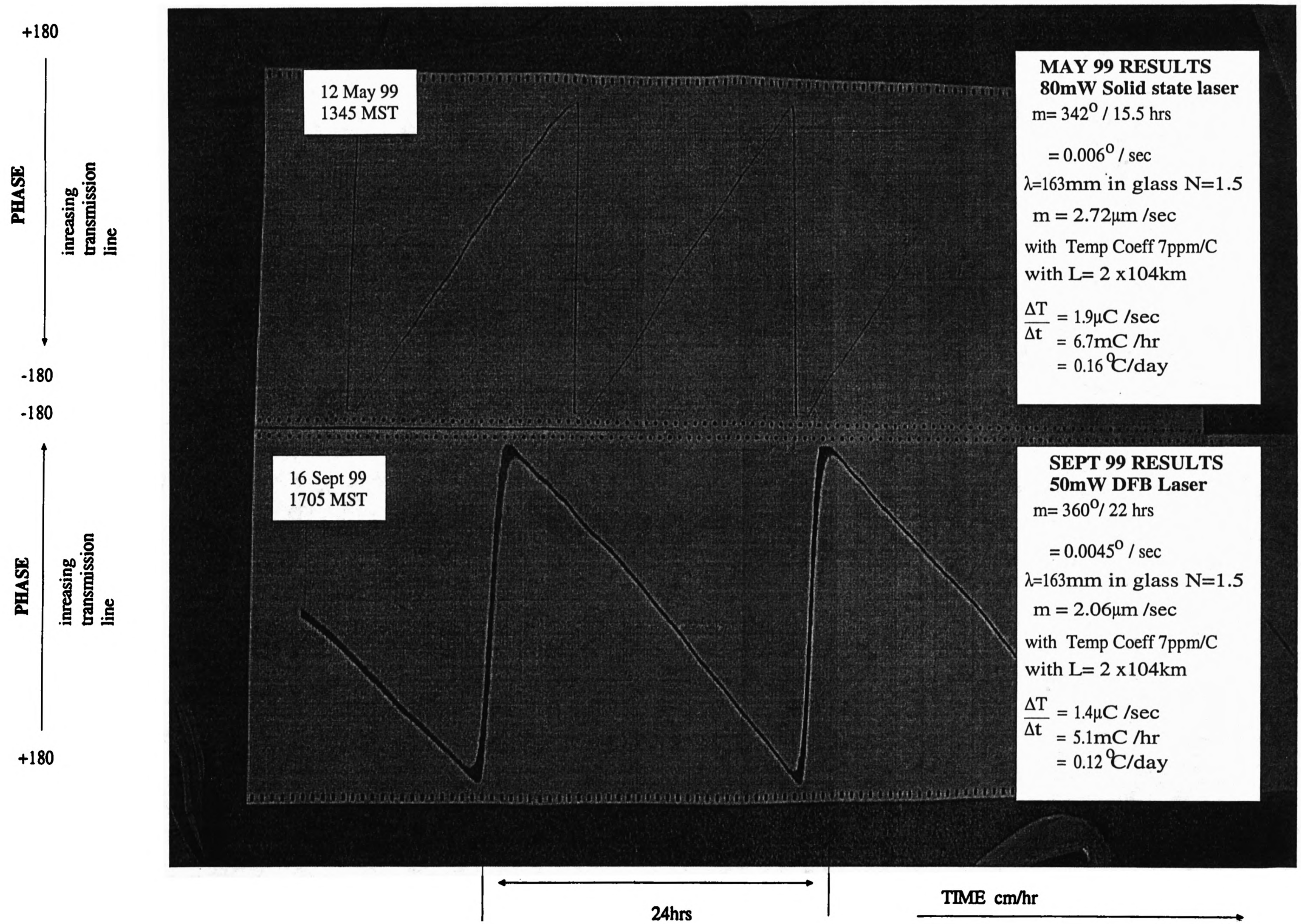
D(T) = 37 ps / C

For a complete turn in phase at 1200MHz (Period 833pS)

The entire 208km section would need ΔT=22 C.........................UNLIKELY

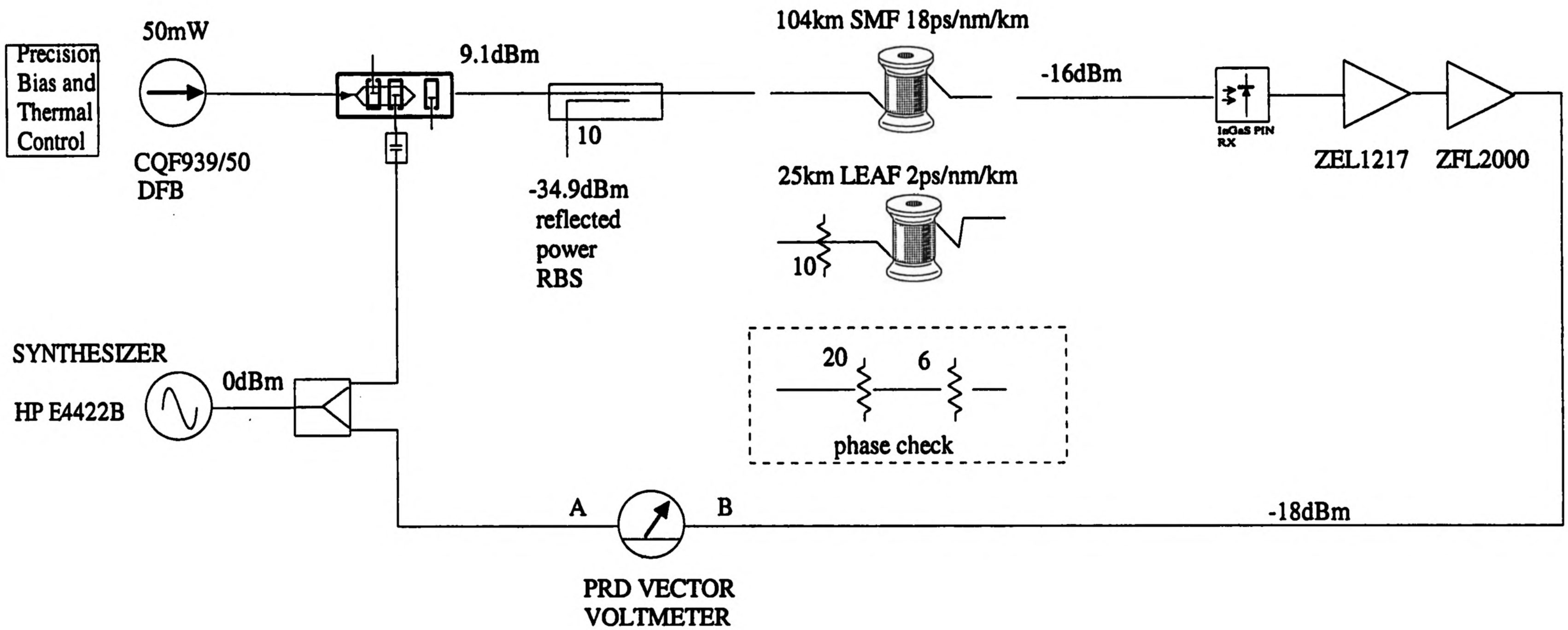
MEASUREMENT OF ROUND TRIP PHASE VLA-PT-VLA @1200MHz 1554nm

rjb 22 Sept 99



PHASE STABILTY OF PT TEST LINK

rjb 9 Sept 99



$V_{thermistor}$ =1104.96mV +/- 0.05mV

Temperature= 26 C +/- 0.001C

λ = 1553.6nm +/- 0.110 picometer

$$\frac{\Delta\lambda}{\Delta T} = \frac{1553.98-1553.66\text{nm}}{26-23\text{ C}}$$

$$= 0.11\text{nm/C}$$

$$\frac{\Delta V}{\Delta T} = 50\text{mV / C} \quad 100\text{uA bias}$$

$$=0.0022\text{nm/mV}$$

PHASE AB RESULTS

With 104km dispersive fiber $\Delta\Phi$ = 6 deg @ 1200MHz in 54secs

With 25km LEAF fiber $\Delta\Phi$ = 1.5 deg @ 1200MHz in 54secs

Since the 104km of fiber with 1870ps/nm of dispersion encountered the same change in RF phase per unit length as the low dispersion 25km fiber total dispersion 50ps/nm the effects of dispersion as a first approximation can be disregarded and all phase effects attributed to the 7ppm /C coefficient of thermal expansion for glass.

$$\lambda_{1200} = \frac{C}{Nf} \quad N=1.5\text{ glass}$$

$$= 163\text{mm}$$

$$T_{1200} = 833\text{ps}$$

$$\frac{\Delta\phi}{\Delta t} = 6\text{deg/54sec}$$

$$\frac{\Delta L}{\Delta T} = 7\text{ppm/C}$$

$$=0.728\text{m/C} \quad \text{for 104km}$$

$$\frac{\Delta L}{\Delta t} = 2.72\text{mm/54secs}$$

$$= 50\mu\text{m/sec}$$

$$\frac{\Delta T}{\Delta t} = \frac{\frac{\Delta L}{\Delta t}}{\frac{\Delta L}{\Delta T}} = \frac{50\mu\text{m}}{728000\mu\text{m}} = 69\mu\text{K/sec}$$

Conclusion - The fiber temperature was changing at 0.25 K /hr

LASER DIODE THERMISTOR Steinhart-Hart Equation

Typical 10k ohm Thermistor performance

$\frac{1}{T} := A + B \cdot \ln(R) + C \cdot (\ln R)^3$ T = deg K R=Ω

$A := 1.1270 \cdot 10^{-3}$ $B := 2.3429 \cdot 10^{-4}$ $C := 8.7298 \cdot 10^{-8}$ some typical constants

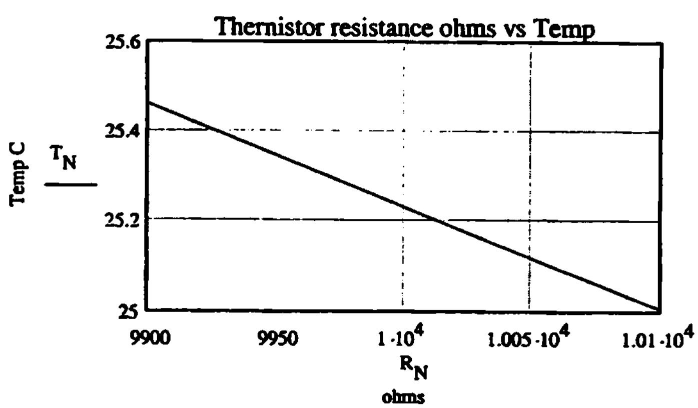
$N := 0, 1 .. 20000$

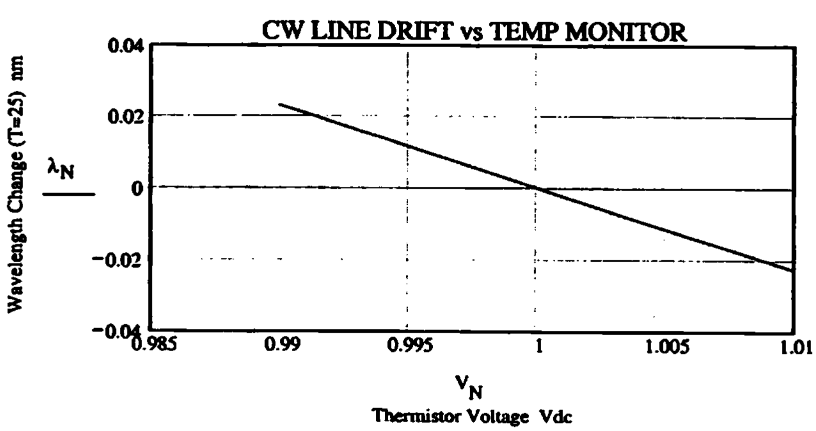
$R_N := 9900 + 0.01 \cdot N$

$$T_N := \left[\left[\frac{1}{A + B \cdot \ln(R_N) + C \cdot (\ln(R_N))^3}\right] - 273\right]$$ deg celcius

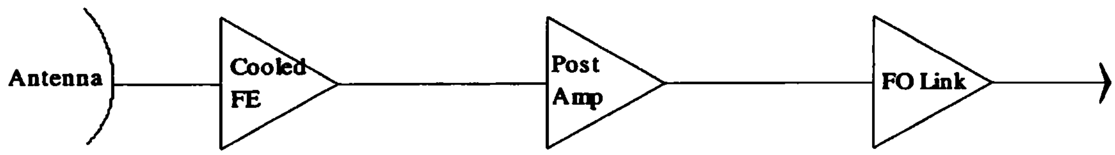
With I bias = 100uA $I_{bias} := 100 \cdot 10^{-6}$ $V_N := I_{bias} \cdot R_N$

$\lambda_N := 0.1 \cdot ((T_N - T_{10000}))$ nm





NOISE FIGURE SPECIFICATION for FIBER LINK



$G_{dB1} := 30\,dB$ $\qquad$ $G_{dB2} := 30 \ \ dB$

$G_1 := 1000$ $\qquad$ $G_2 := 1000$ $\qquad$ $T_3 \ = ?$

$T_1 := 20 \quad k$ $\qquad$ $T_2 := 500 \quad k$

$$NF_1 := 10 \cdot \log\left(\frac{T_1 + 290}{290}\right)$$

$NF_1 = 0.29 \quad dB$

$T_{sys} := 30 \qquad T_{ant} := 5 \qquad T_{feed} := 4 \qquad T_{spill} := 1$

The system temperature $\quad T_{sys} = \ T_{ant} + T_{feed} + T_{spill} + T_{amplifiers}$

Specification : The Fiber Optic Link shall not degrade the system temperature by more than 1%.

$i := 0..500$

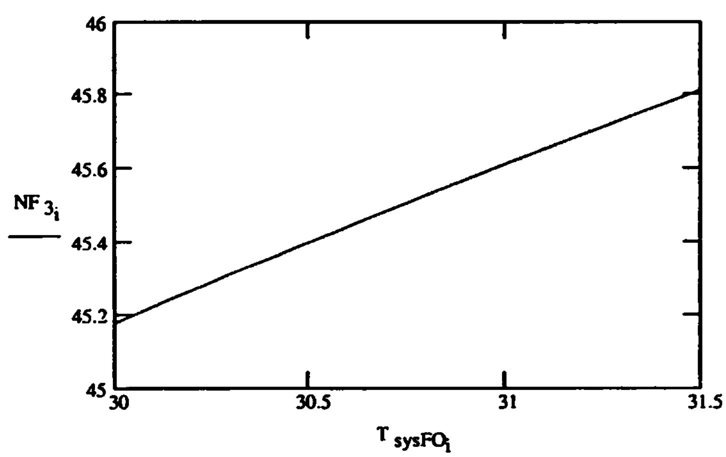
$$T_{sysFO_i} := T_{sys} \cdot \left(1 + \frac{i}{10000}\right)$$

now $\quad T_{sysFO} \ = \ T_1 + \frac{T_2}{G_1} + \frac{T_3}{G_1 \cdot G_2}$

$$T_{3_i} := \left(T_{sysFO_i} - T_1 - \frac{T_2}{G_1}\right) \cdot G_1 \cdot G_2$$

$$EIN_{3_i} := 10 \cdot \log\left(1.38 \cdot 10^{-20} \cdot T_{3_i}\right)$$

$NF_{3_i} := EIN_{3_i} + 174$



THE CALCULATION of RAYLEIGH BACKSCATTER

rjb 30 Dec 98

From data supplied by ALCATEL namely the RBS (Rayleigh Backscatter coefficient)

RBS = -81.7dB / m @1550nm

It is possible to calculate the ORL (Optical Return Loss) at given lengths of fiber.
HP quotes a value of RBS=-73dB/m

$RBS := -73. \quad \frac{dB}{m}$

$R_{rbs} := 10^{\frac{RBS}{10}} \quad \frac{1}{m}$ expressed as a ratio

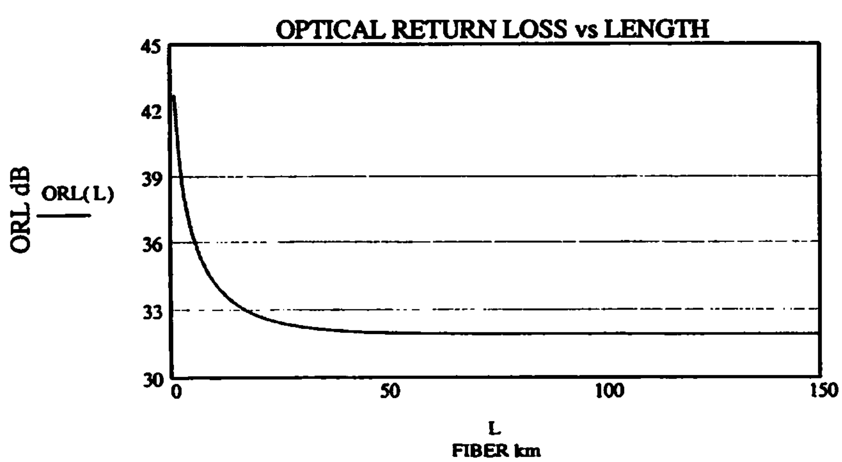
$\alpha_s := 3.9 \cdot 10^{-5} \quad \frac{1}{m}$ Rayleigh scattering attenuation only about 0.17dB /m

$S := \frac{R_{rbs}}{\alpha_s} \quad S = 1.285 \cdot 10^{-3}$ The Scatter Capture Ratio

$\alpha_{db} := 0.19 \quad \frac{db}{km} \quad \alpha := \frac{\alpha_{db}}{10 \cdot \log(e^1)} \quad \alpha = 0.044$ loss per km

$L := 0 .. 150$

$$ORL(L) := -10 \cdot \log\left[\left(\frac{S}{2}\right) \cdot \left(1 - e^{-2 \cdot \alpha \cdot L}\right)\right]$$



ANALYSIS PROGRAM
FOR Pie Town to VLA ANALOG FIBER OPTIC LINK
USING EXTERNAL MODULATION & EDFA Headend

Designed : Ron Beresford March 98
SFDR calculation modified 1Sept 98

$N := 40$

$i := 0..N$

$L_i := i$ dB $\qquad Lf_i := 10^{-\left(\frac{L_i}{10}\right)}$ All losses excluding modulator

$P_{laser} := 50 \cdot 10^{-3}$ W $\qquad P_{laserdBm} := 10 \cdot \log\left(\frac{P_{laser}}{10^{-3}}\right) \qquad Laser := \frac{P_{laser}}{10^{-3}}$ mW

$L_{mod} := 3.7$ dB $\qquad L_{bias} := 3$ dB $\qquad G_{EDFA} := 0$ dB $\qquad NF_{EDFA} := 0$ dB

$P_{idBm} := P_{laserdBm} - L_{mod} - L_{bias} + G_{EDFA}$

$P_{in} := 10^{-3} \cdot 10^{\left(\frac{P_{idBm}}{10}\right)}$ W $\qquad$ Launched into SMF

$I_{dark} := 1 \cdot 10^{-9}$ A $\qquad e := 1.6 \cdot 10^{-19}$ C

$\eta := 0.80 \quad \frac{A}{W}$

$Pout_i := Lf_i \cdot P_{in}$ W

$\Delta f := 200 \cdot 10^{6}$ Hz

$R_{out} := 50$ Ω

$k := 1.38 \cdot 10^{-23} \quad \frac{W}{K \cdot Hz} \qquad T := 300$ K

$RIN_{laser} := -160 \quad \frac{db}{Hz}$

$N_{shot_i} := 2 \cdot e \cdot \left(\eta \cdot Pout_i + I_{dark}\right) \cdot R_{out} \cdot \Delta f$ W

$N_{th_i} := k \cdot T \cdot \Delta f$ W

$N_{RINdBm_i} := \left(P_{idBm} + RIN_{laser} + NF_{EDFA}\right) - L_i + 10 \cdot \log(\Delta f)$

$N_{RINdBw_i} := N_{RINdBm_i} - 30$

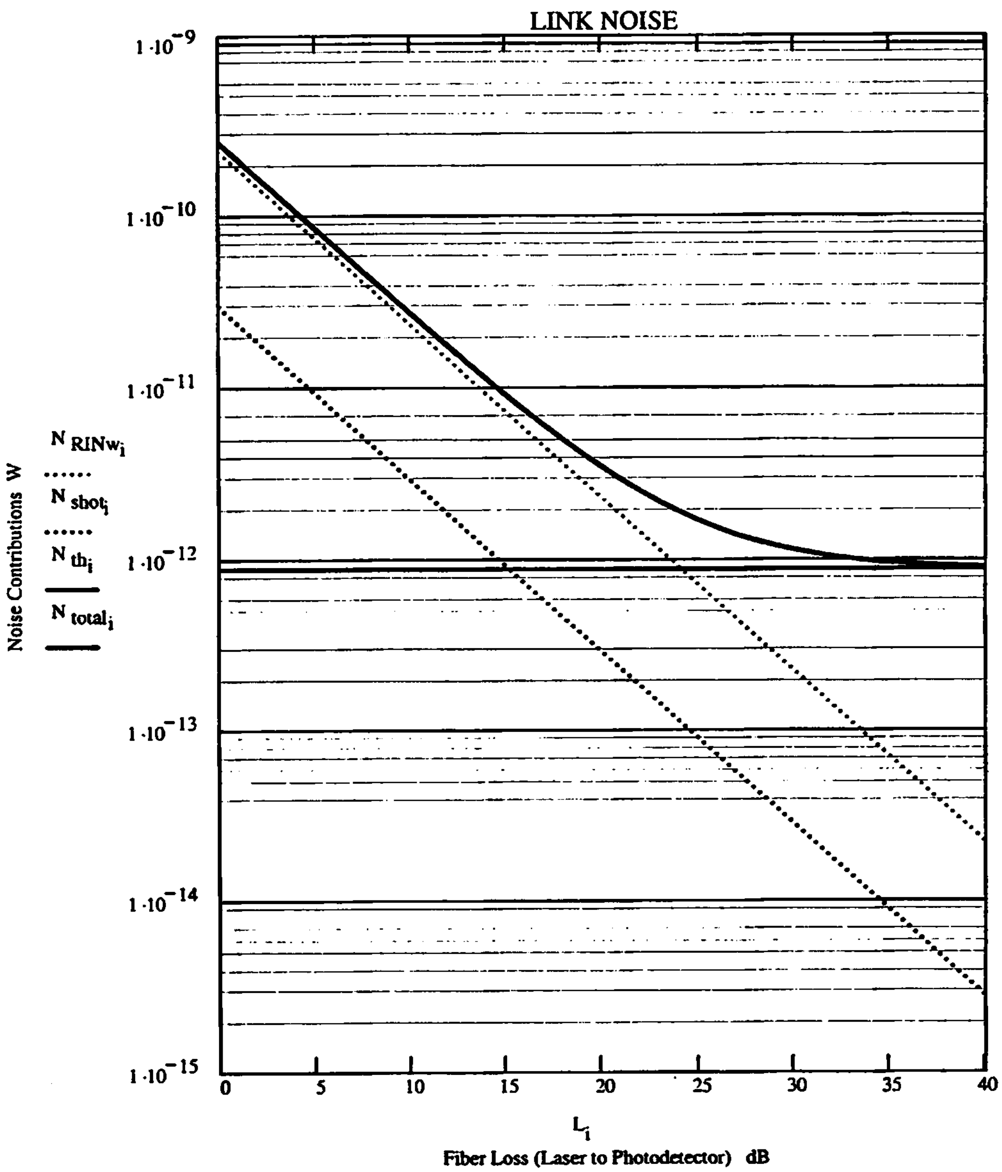
$N_{RINw_i} := 10^{\left(\frac{N_{RINdBw_i}}{10}\right)}$

$N_{total_i} := N_{RINw_i} + N_{th_i} + N_{shot_i}$

$P_{idBm} = 10.29$ dBm

$Pin_{mw} := \frac{P_{in}}{10^{-3}}$

$Pin_{mw} = 10.69$ mW



$$\text{Optimum} := \left| \begin{array}{l} j \leftarrow 0 \\ \text{while } \left(N_{shot_j} \geq N_{th_j}\right) \\ \quad j \leftarrow j + 1 \\ j \end{array} \right.$$

$L_{Optimum} = 16$ dB ie the maximum suggested loss allowed

$R_p := 50$ $\quad V_\pi := 2.7$ $\quad N_d := 1$

Photodetector
impedance
match turns ratio

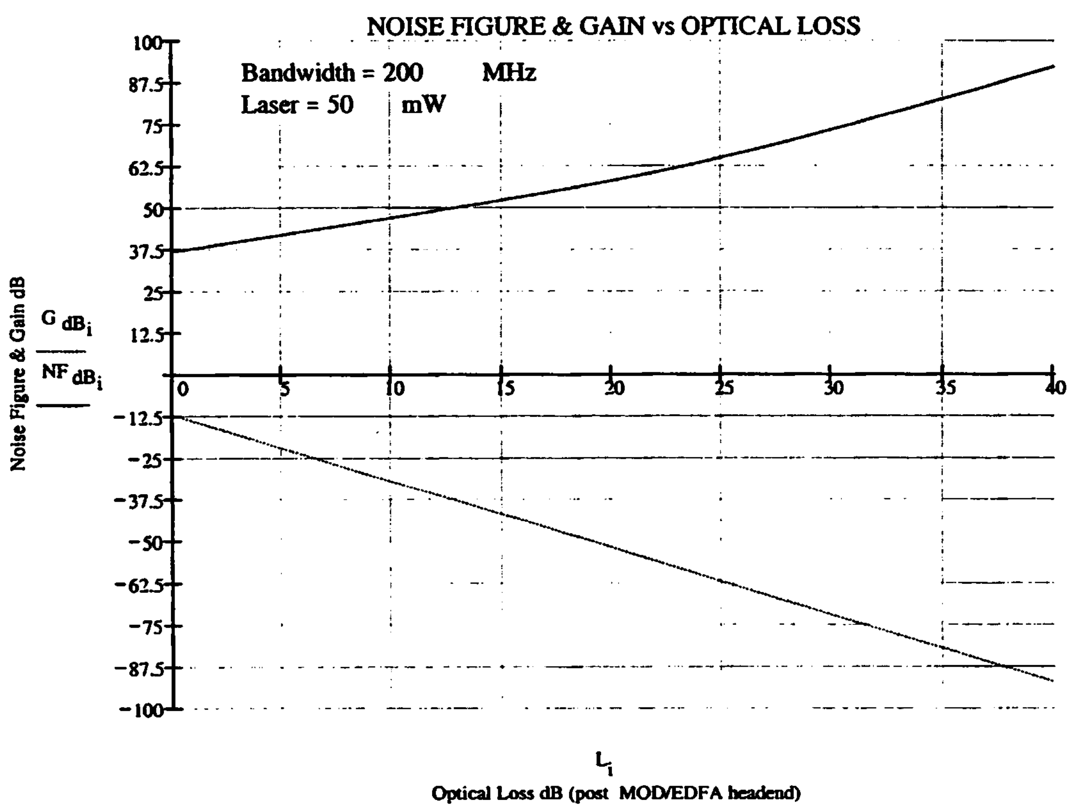
$$G_i := \left(\frac{Lf_i \cdot P_{in} \cdot \pi \cdot \eta \cdot N_d}{2 \cdot V_\pi}\right)^2 \cdot R_{out} \cdot R_p$$

$$G_{dB_i} := 10 \cdot \log(G_i)$$

$$NF_i := \frac{N_{total_i}}{k \cdot T \cdot \Delta f \cdot G_i}$$

$$NF_{dB_i} := 10 \cdot \log(NF_i)$$

$$\text{Bandwidth} := \frac{\Delta f}{10^6}$$



$$P_{IP3in} := 10 \cdot \log\left(\frac{8 \cdot V_{\pi}^{2}}{2 \cdot \pi^{2} \cdot R_{p}}\right) + 30$$

$P_{IP3in} = 17.715$ dBm

TOI in dBm

$$IP3_{2_i} := G_i \cdot 10^{\left(\frac{P_{IP3in}}{10}\right)}$$

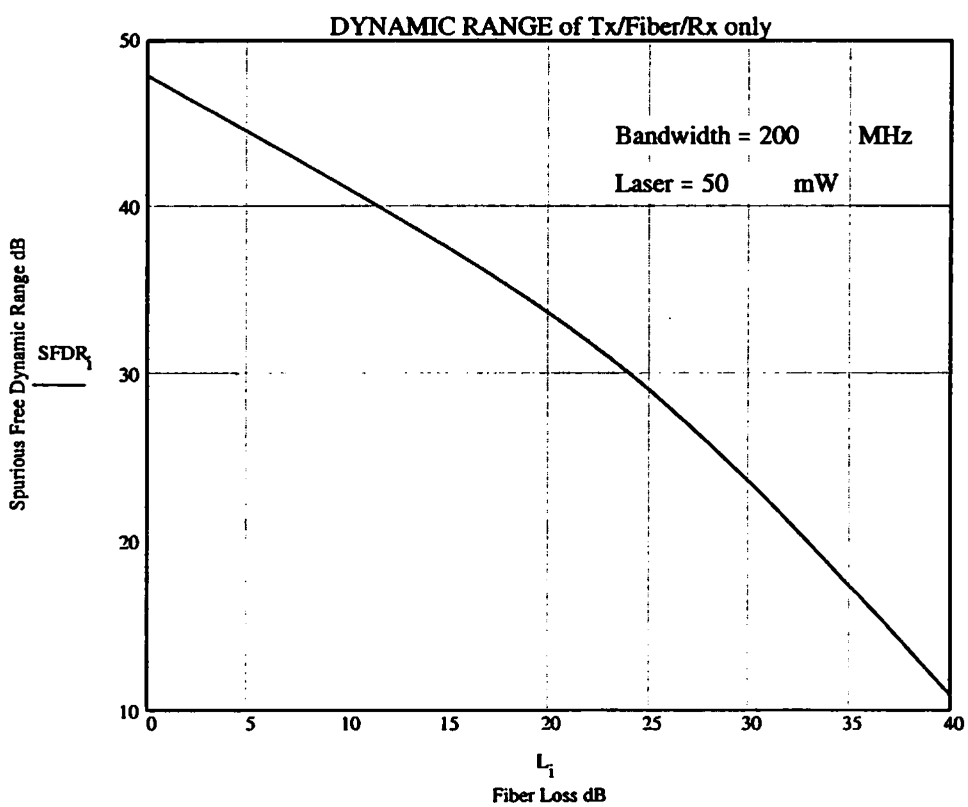
$$N_{floor} := 10 \cdot \log(k \cdot T) + 30$$

$$mds_i := N_{floor} + 10 \cdot \log(\Delta f) + NF_{dB_i}$$

Perfect Noise floor at Modulator dBm/Hz

$$SFDR_i := \frac{2}{3} \cdot \left(P_{IP3in} - mds_i\right)$$

the minimum detecteable signal dBm
at the input to modulator



Postamplifier constants

ZEL 1217 ZKL-2 ZFL2500

$G_{dB3} := 65$ $\qquad G_3 := 10^{\left(\frac{G_{dB3}}{10}\right)}$

$NF_{dB3} := 2$ $\qquad NF_3 := 10^{\left(\frac{NF_{dB3}}{10}\right)}$

$IP3_{dBm3} := 35$ $\qquad IP3_3 := 10^{\left(\frac{IP3_{dBm3}}{10}\right)}$ mW

$NF_{cascade_i} := NF_i + \left(\frac{NF_3 - 1}{G_i}\right)$ $\qquad NF_{cascadedB_i} := 10 \cdot \log\left(NF_{cascade_i}\right)$

$IP3_{cascade_i} := \left(\frac{1}{IP3_3} + \frac{1}{G_3 \cdot IP3_{2_i}}\right)^{-1}$ mW $\qquad IP3_{cascadedBm_i} := 10 \cdot \log\left(IP3_{cascade_i}\right)$ dBm

$G_{cascadedB_i} := G_{dB_i} + G_{dB3}$

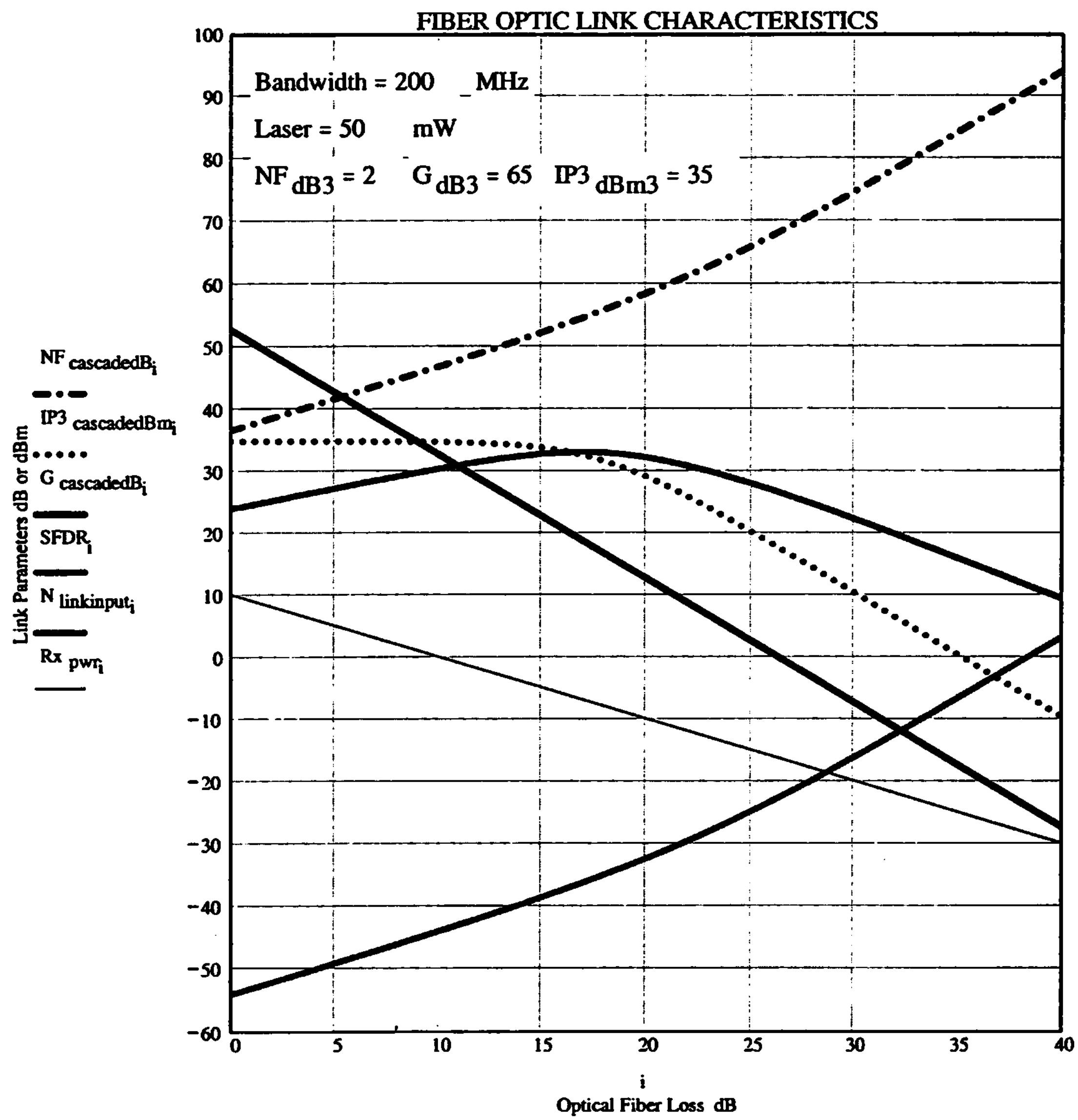
$mds_i := \left(N_{floor} + 10 \cdot \log(\Delta f) + NF_{cascadedB_i}\right) + G_{cascadedB_i}$ at link output

$SFDR_i := \frac{2}{3} \cdot \left(IP3_{cascadedBm_i} - mds_i\right)$

$N_{linkinput_i} := N_{floor} + 10 \cdot \log(\Delta f) + NF_{cascadedB_i}$ in total bandwidth

$SFDRin_i := \left(IP3_{cascadedBm_i} - G_{cascadedB_i} - N_{linkinput_i}\right) \cdot \frac{2}{3}$

$Rx_{pwr_i} := P_{idBm} - i$


FIBER OPTIC LINK CHARACTERISTICS
Bandwidth = 200 MHz
Laser = 50 mW
NF dB3 = 2
G dB3 = 65
IP3 dBm3 = 35
NF cascadedB_i
IP3 cascadedBm_i
G cascadedB_i
SFDR_i
N linkinput_i
Rx pwr_i
Link Parameters dB or dBm
i
Optical Fiber Loss dB
100
90
80
70
60
50
40
30
20
10
0
−10
−20
−30
−40
−50
−60
0
5
10
15
20
25
30
35
40

$i := 0..30 \qquad q := 26$

$SFDR_q = 27.1 \qquad G_{cascadedB_q} = 0.9 \qquad N_{linkinput_q} = -23.1$ dBm

Let $SNR := 20\,dB \qquad Pmodsignal_{dBm_i} := N_{linkinput_i} + SNR$

$P_{mod100\%} := \dfrac{V_\pi^{\,2} \cdot 10^3}{8 \cdot R_p} \qquad P_{mod100\%} = 18.2$ mW

$Pmodsignal_{dBm_q} = -3.1 \qquad Pmodsignal_{mW_i} := 10^{\left(\frac{Pmodsignal_{dBm_i}}{10}\right)}$

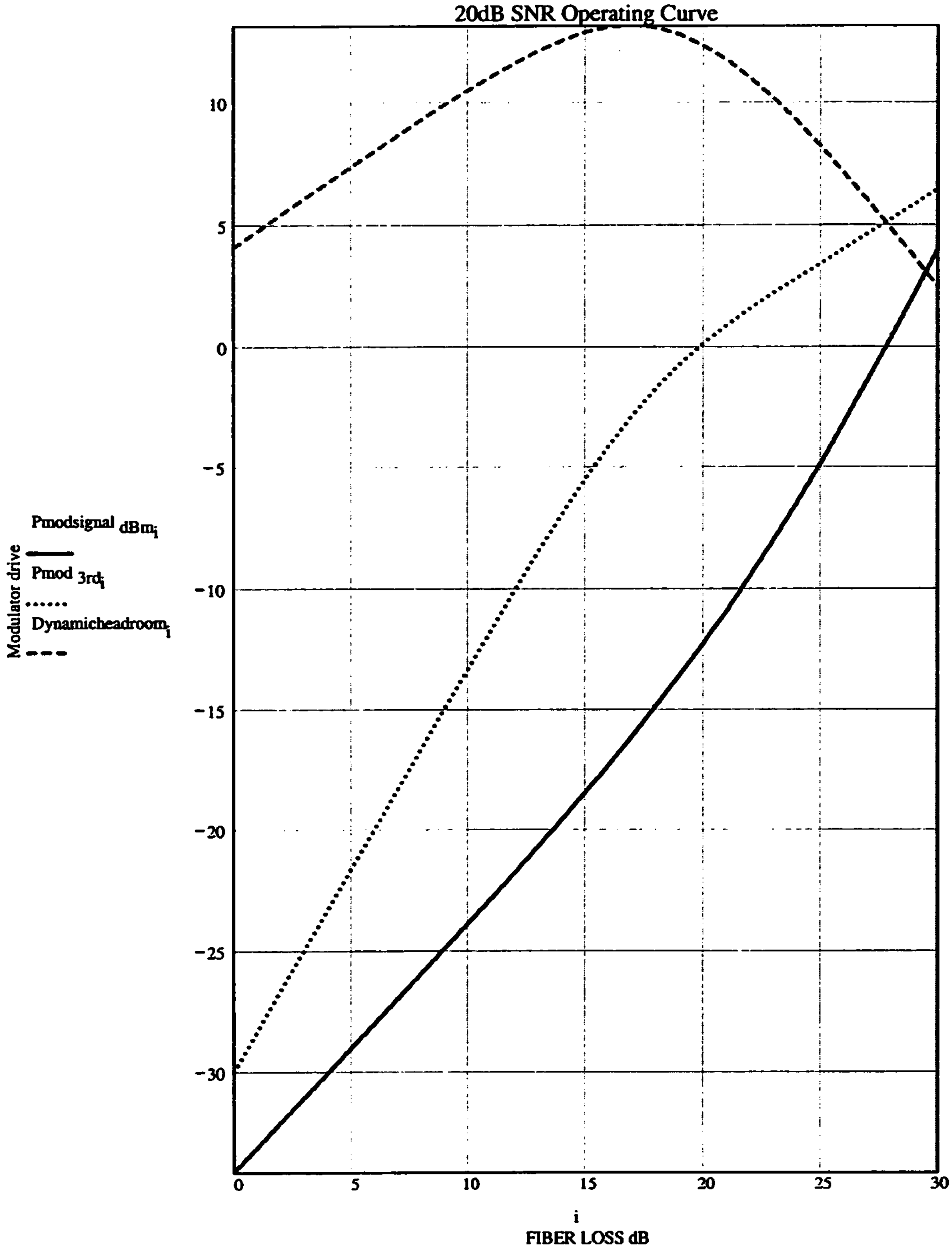
$P_{out_i} := G_{cascadedB_i} + Pmodsignal_{dBm_i}$

$\%MODULATION_i := \dfrac{Pmodsignal_{mW_i}}{P_{mod100\%}} \cdot 100$ at typical signal level

$\%MODULATION_q = 2.7$ %

$Pmod_{3rd_i} := N_{linkinput_i} + SFDR_i$

$Dynamicheadroom_i := SFDR_i - SNR$



20dB SNR Operating Curve
Modulator drive
Pmodsignal dBm_i
Pmod 3rd_i
Dynamicheadroom_i
10
5
0
-5
-10
-15
-20
-25
-30
0
5
10
15
20
25
30
i
FIBER LOSS dB

STIMULATED BRILLOUIN SCATTER

Attenuation (km) $\alpha_{km} := 0.21$ $\frac{dB}{km}$ $\alpha := \frac{\alpha_{km}}{1000}$ $\frac{dB}{m}$

Fiber Core Diameter $\phi := 8$ μm $A_{eff} := \pi \cdot \left(\frac{\phi \cdot 10^{-6}}{2}\right)^2$ m^2

Polarization Factor 1< k < 2

Brillouin gain factor $g_b := 4.6 \cdot 10^{-11}$ $\frac{m}{W}$

$i := 1 .. 120$

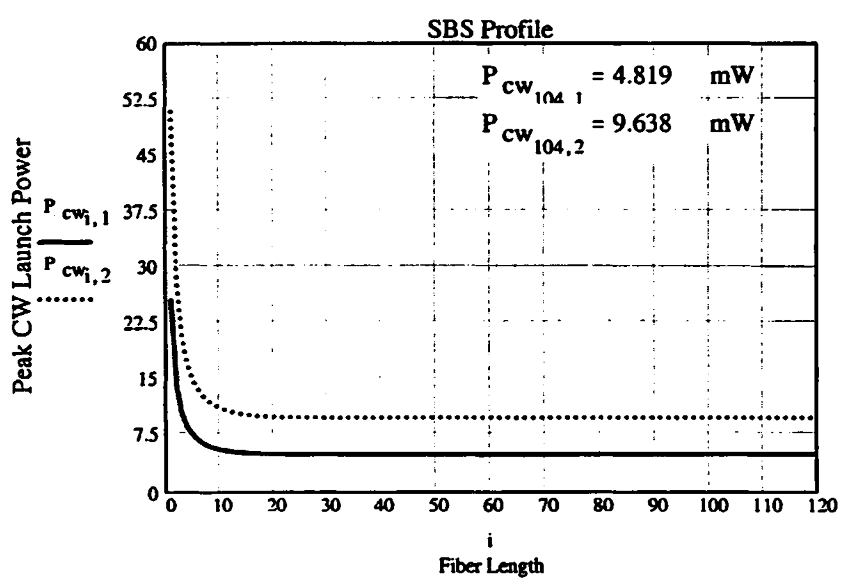
Length of cable $L_i := i$ km $L_{m_i} := L_i \cdot 1000$ m

$$L_{e_i} := \frac{1 - e^{-\alpha \cdot L_{m_i}}}{\alpha}$$

$k := 1 .. 2$

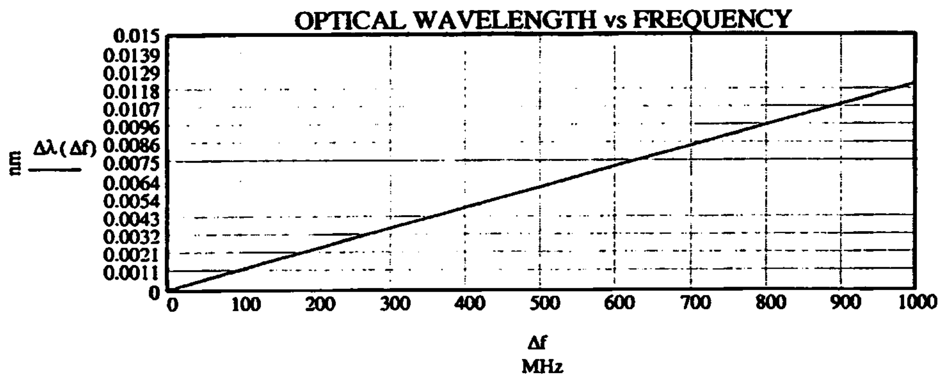
$$P_{cw_{i,k}} := 21 \cdot \frac{A_{eff} \cdot k}{g_b \cdot L_{e_i}} \cdot 1000 \quad \text{mW}$$

$$P_{dBm_{i,k}} := 10 \cdot \log\left(\frac{P_{cw_{i,k}}}{0.001}\right)$$

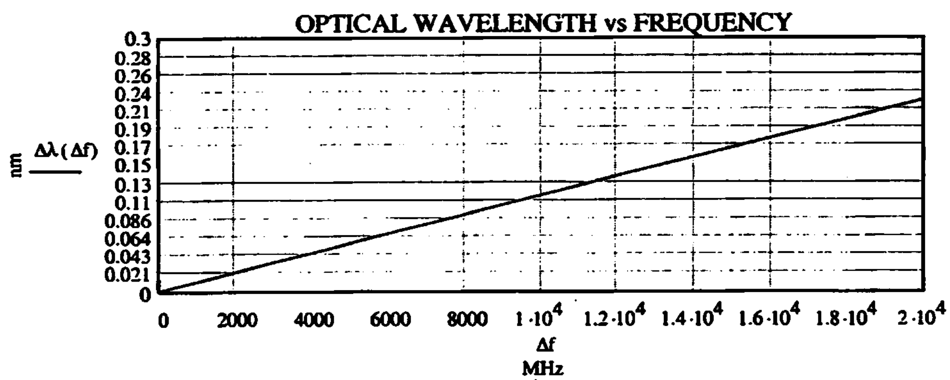


OPTICAL WAVELENGTH vs FREQUENCY READY RECKONER

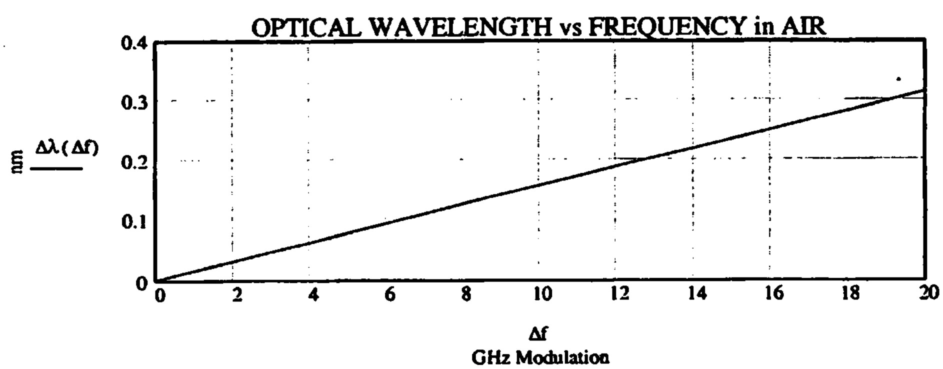
$v := \frac{3 \cdot 10^8}{1.5}$ $\quad f := \frac{v}{1554 \cdot 10^{-9}}$ $\quad \Delta f := 0, 10 .. 1000$ $\quad \Delta\lambda(\Delta f) := \frac{v \cdot \Delta f \cdot 10^6}{(f)^2 \cdot 10^{-9}}$



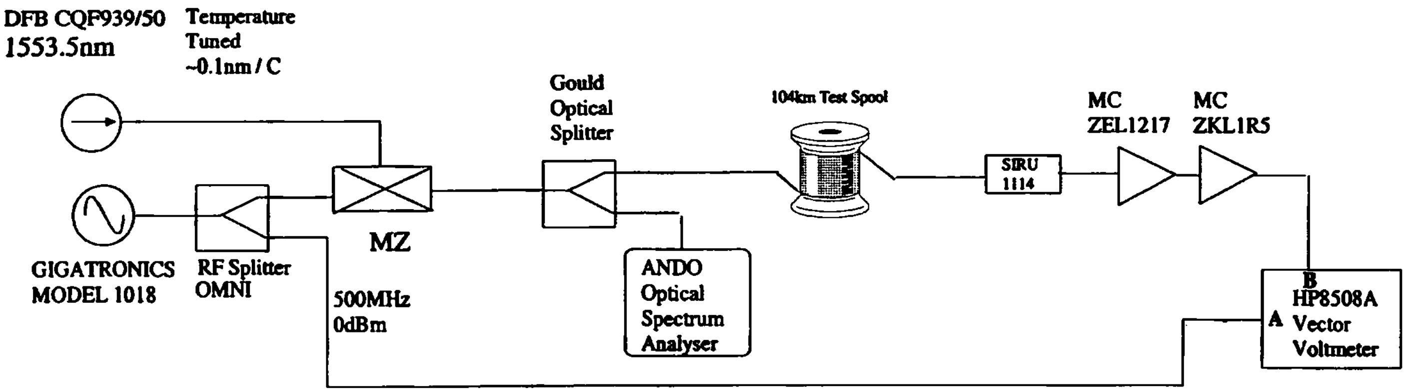
$v := \frac{3 \cdot 10^8}{1.4}$ $\quad f := \frac{v}{1554 \cdot 10^{-9}}$ $\quad \Delta f := 0, 100 .. 20000$ $\quad \Delta\lambda(\Delta f) := \frac{v \cdot \Delta f \cdot 10^6}{(f)^2 \cdot 10^{-9}}$



$v := \frac{3 \cdot 10^8}{1}$ $\quad f := \frac{v}{1554 \cdot 10^{-9}}$ $\quad \Delta f := 0, 1 .. 20$ GHz $\quad \Delta\lambda(\Delta f) := \frac{v \cdot \Delta f \cdot 10^9}{(f)^2 \cdot 10^{-9}}$



ALCATEL FIBER DISPERSION MEASUREMENT



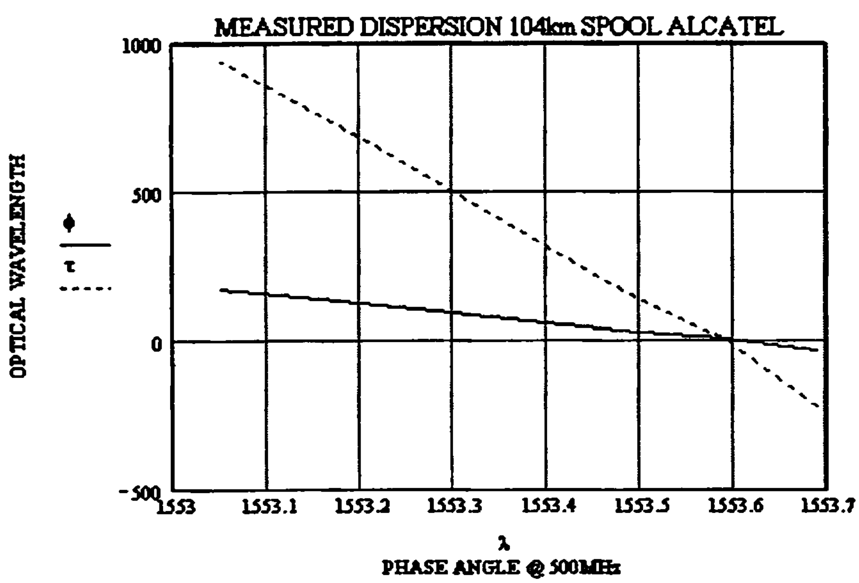
Results

$$\lambda := \begin{bmatrix} 1553.69 \\ 1553.59 \\ 1553.56 \\ 1553.50 \\ 1553.46 \\ 1553.22 \\ 1553.05 \end{bmatrix} \qquad \phi := \begin{bmatrix} -40 \\ 0 \\ 8 \\ 25 \\ 37 \\ 116 \\ 169 \end{bmatrix}$$

$f := 500 \cdot 10^{6}$ Hz

$T := \dfrac{1}{f \cdot 10^{-12}}$ $\quad T = 2 \cdot 10^{3}$ ps

$\tau := \dfrac{T}{360} \cdot \phi$ ps delay

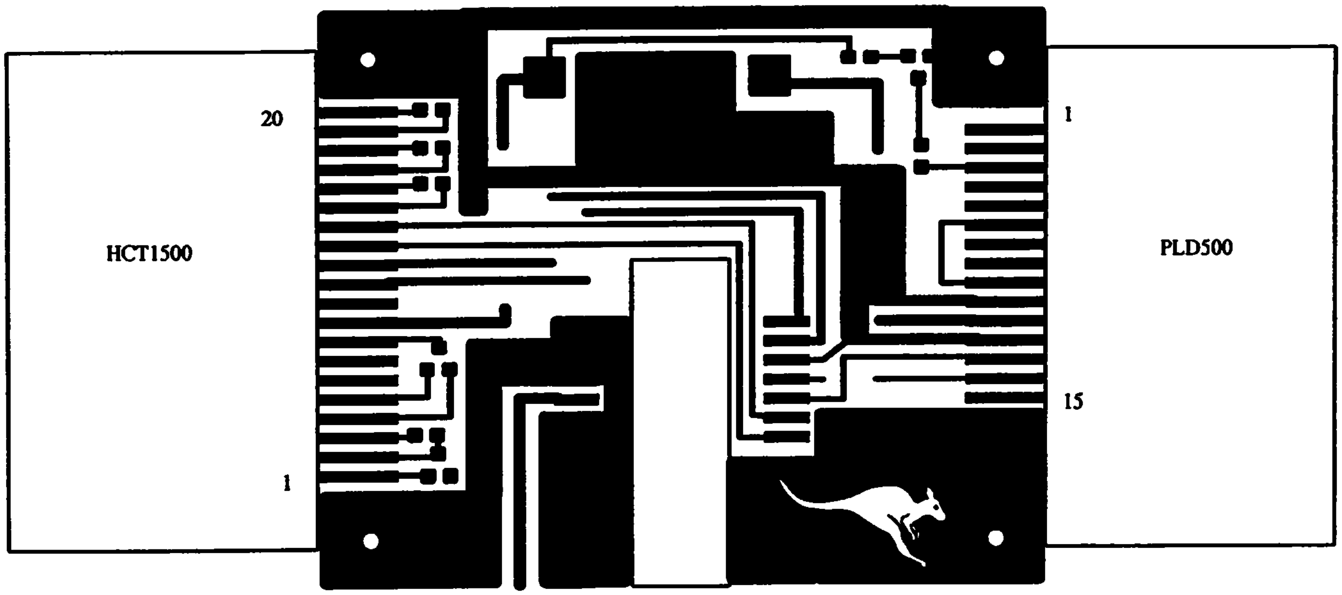


$\text{slope}(\lambda, \tau) = -1.788 \cdot 10^{3}$ $\dfrac{ps}{nm}$

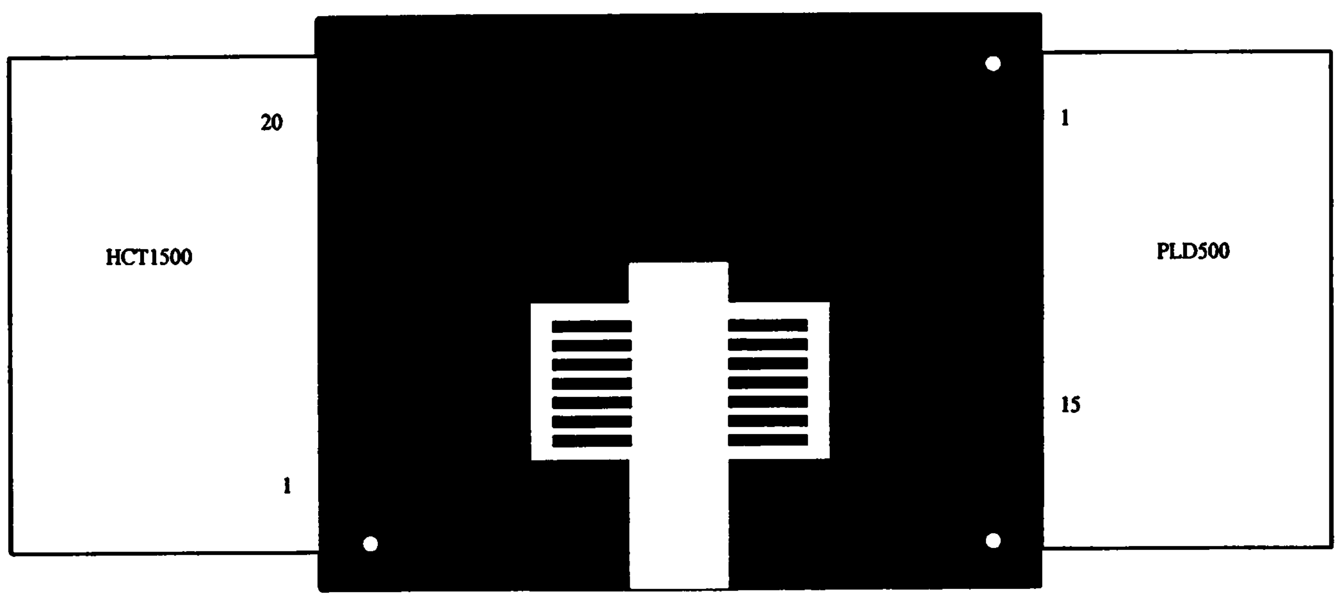
The dispersion is 1790 ps/nm at 1553.5 nm

rjb 30 Sept 99

TOP

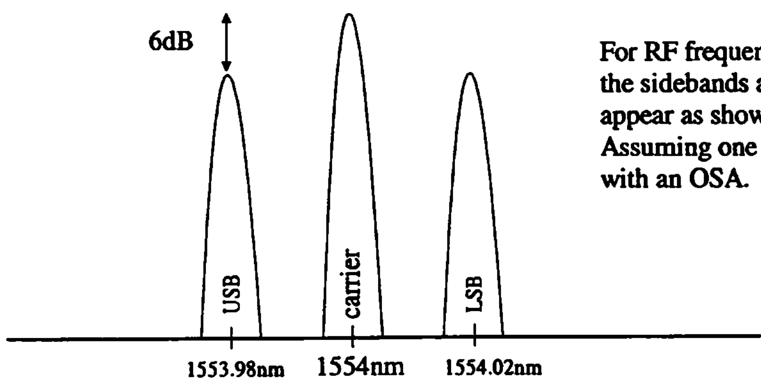


BOTTOM



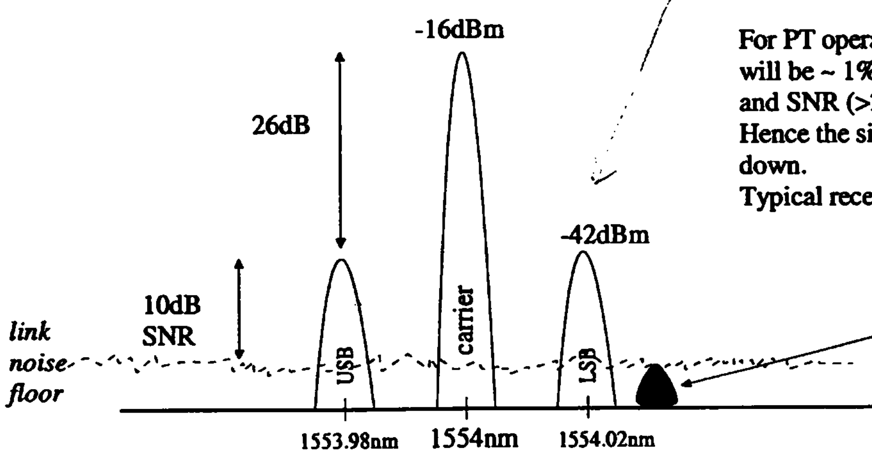
ANALOG CHANNEL SIDEBAND ISOLATION

With analog intensity modulation an optical carrier modulated at 100% depth will have half the optical power in the two sidebands.ie the individual sideband power will be -6dBc.



For RF frequencies at 2GHz ~0.02nm the sidebands at 100% modulation will appear as shown.
Assuming one could resolve such spectra with an OSA.

Modulation sidebands



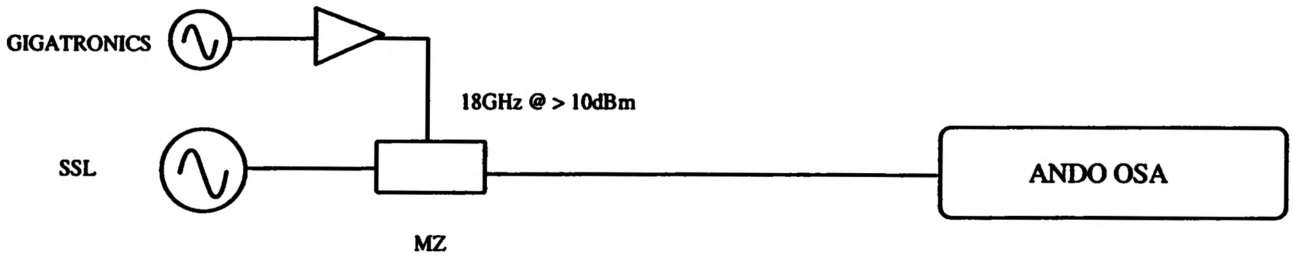
For PT operation the modulation depth will be ~ 1% to maintain adequate linearity and SNR (>20dB).
Hence the sidebands will be another 20dB down.
Typical receive power levels are shown,

Interfering optical spectra from adjacent WDM channels must be kept atleast 20dBelectrical below the analog signal level..

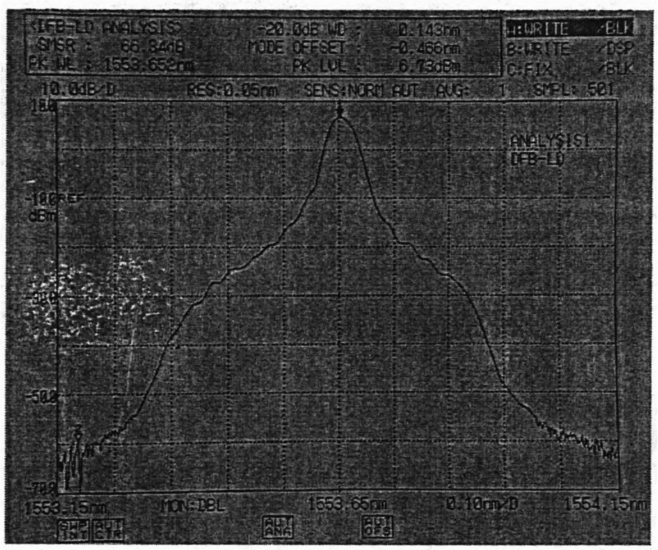
The analog signal is represented by a total optical power of -39dBm.
The associated noise floor is 20dB electrical below this ,or 10dB optical below -39dBm as predicated by photodetction square law.
Optical link noise floor is -49dBm.

All interferring optical channels within the WDM channle should total less than -49dBm optical.

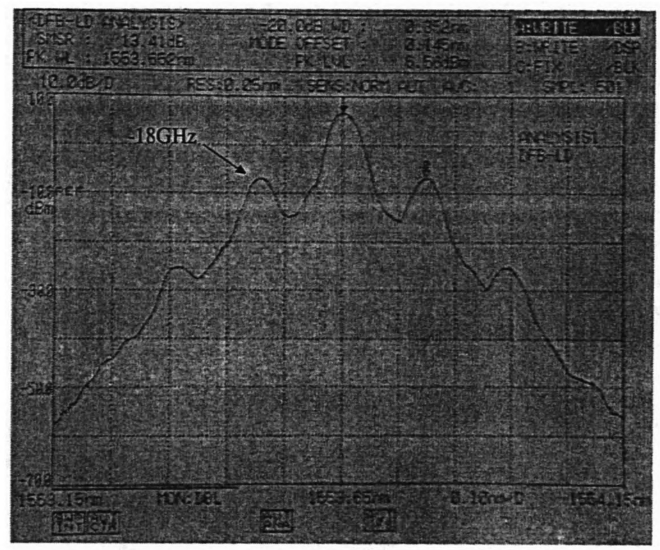
DSB INTENSITY MODULATION OPTICAL SPECTRUM



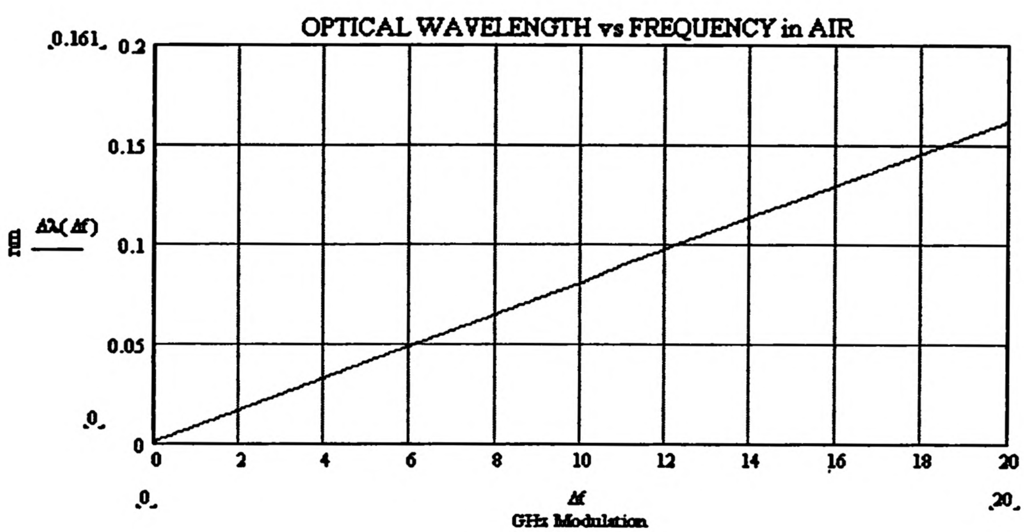
UNMODULATED CARRIER



MODULATED CARRIER

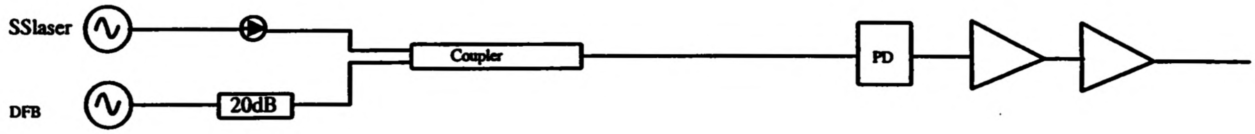


Sidebands at 18GHz
0.14nm in air (OSA reading)
0.21nm in fiber
~10% OMI

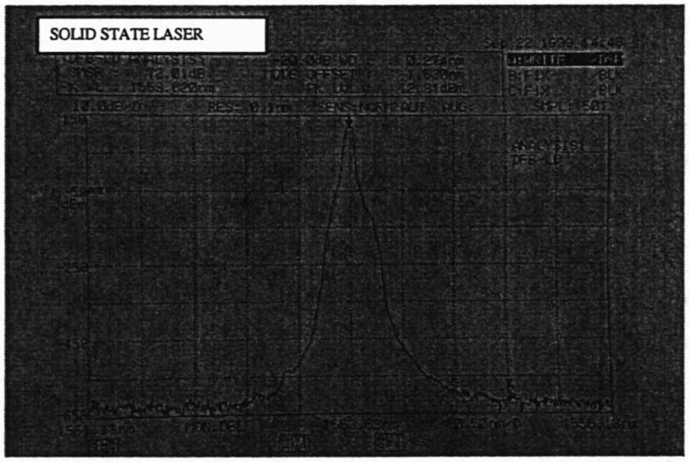


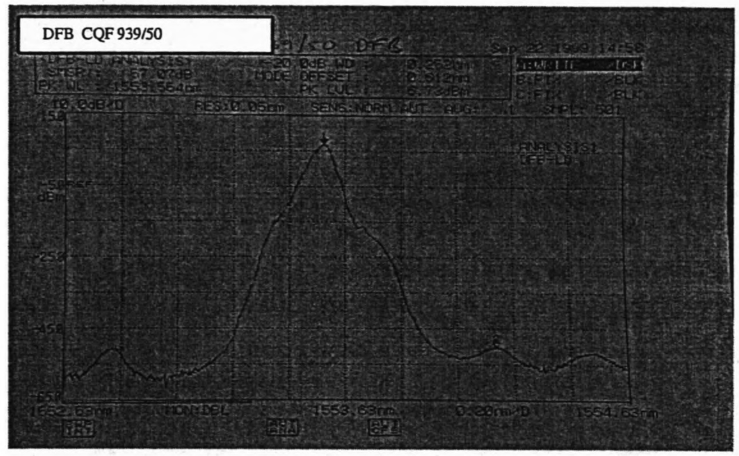
LASER SPECTRUM by OPTICAL MIXING

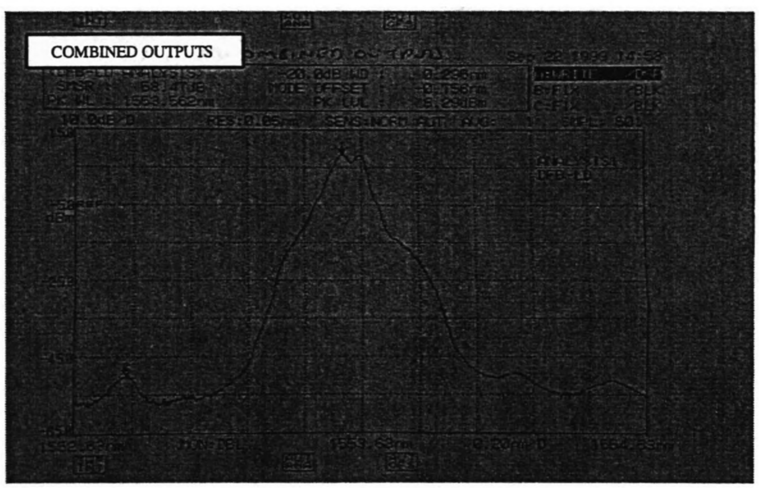
rjb 24 sept 99

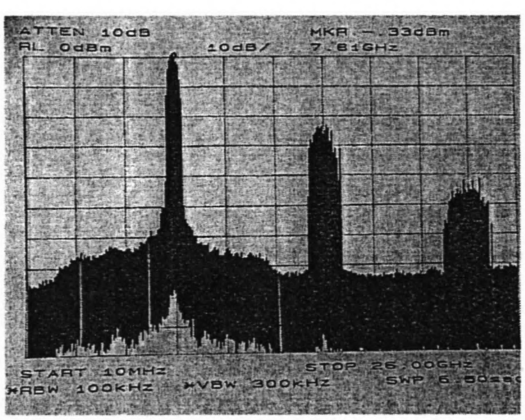


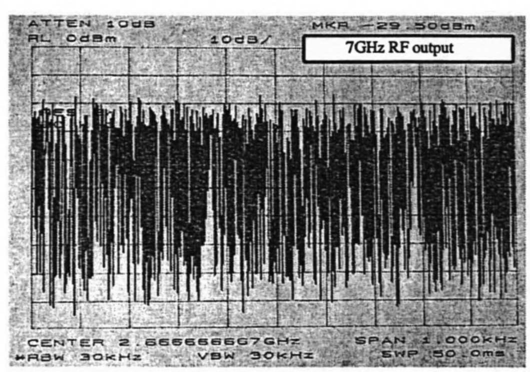
In this configuration a photodiode was used as a photonic mixer to beat two lasers seperated by 7GHz (<0.1nm)
The wavelength of the DFB was trimmed using temperature control to provide this offset.
The longterm drift (hrs) was less than 2GHz or (0.02nm) after warm up..





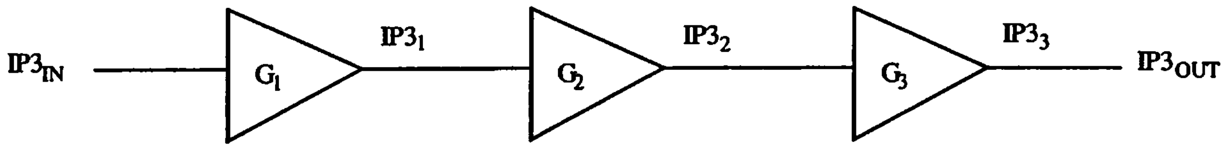






IP3anlys.drw

CASCADE ANALYSIS OF THIRD ORDER INTERCEPT

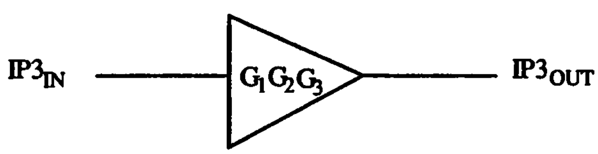


The third order intercept values $IP3_1$ $IP3_2$ $IP3_3$ are the respective stage values refered to outputs in (mW)

Hence

$$IP3_{OUT} = \left[\frac{1}{IP3_3} + \frac{1}{G_3\ IP3_2} + \frac{1}{G_2\ G_3\ IP3_1} \right]^{-1}$$

Referred to input



Thus

$$IP3_{IN} = \frac{IP3_{OUT}}{G_1 G_2 G_3}$$

$$= \left[\frac{1}{IP3_3} + \frac{1}{G_3\ IP3_2} + \frac{1}{G_2\ G_3\ IP3_1} \right]^{-1} * \frac{1}{G_1 G_2 G_3}$$

$$= \left[\frac{G_1}{IP3_1} + \frac{G_1 G_2}{IP3_2} + \frac{G_1 G_2 G_3}{IP3_3} \right]^{-1}$$

NB : Beware of the output or the input reference plane

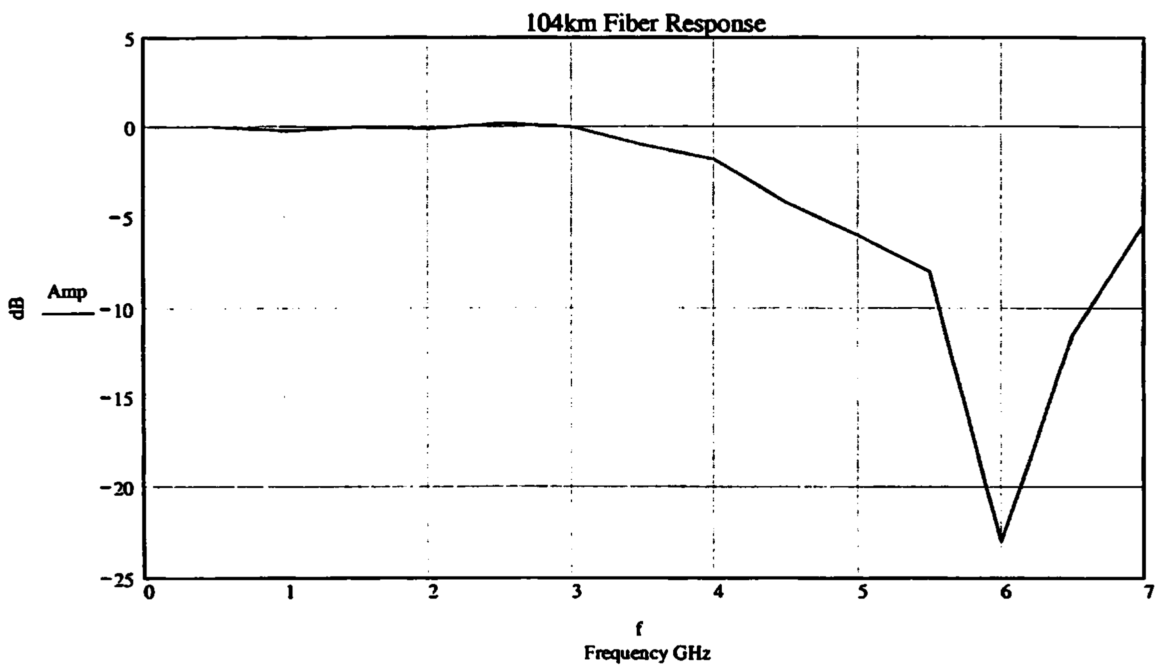
ALCATEL FIBER BANDPASS 104km
USING EXTERNAL MODULATION
12GHz UTP MZ MODULATOR
50mW DFB
18GHz Lasertron PIN Diode
104km SMF Test Spool

Limited by Chromatic Dispersion of glass

Oct 99

$$f := \begin{bmatrix} 0.5 \\ 1 \\ 1.5 \\ 2 \\ 2.5 \\ 3 \\ 3.5 \\ 4 \\ 4.5 \\ 5 \\ 5.5 \\ 6 \\ 6.5 \\ 7 \end{bmatrix} \quad Cal := \begin{bmatrix} -49 \\ -45.8 \\ -46.6 \\ -47.5 \\ -48 \\ -49 \\ -49.3 \\ -49 \\ -48.6 \\ -50.3 \\ -57 \\ -54 \\ -53 \\ -53.6 \end{bmatrix} \quad Meas := \begin{bmatrix} -49 \\ -46 \\ -46.6 \\ -47.6 \\ -47.8 \\ -49 \\ -50.3 \\ -50.8 \\ -52.8 \\ -56.3 \\ -65 \\ -77 \\ -64.5 \\ -59 \end{bmatrix}$$

$$Amp := Meas - Cal$$



ANALYSIS of EXTERNALLY MODULATED ANALOG FIBER OPTIC LINK

Ron Beresford Feb 98

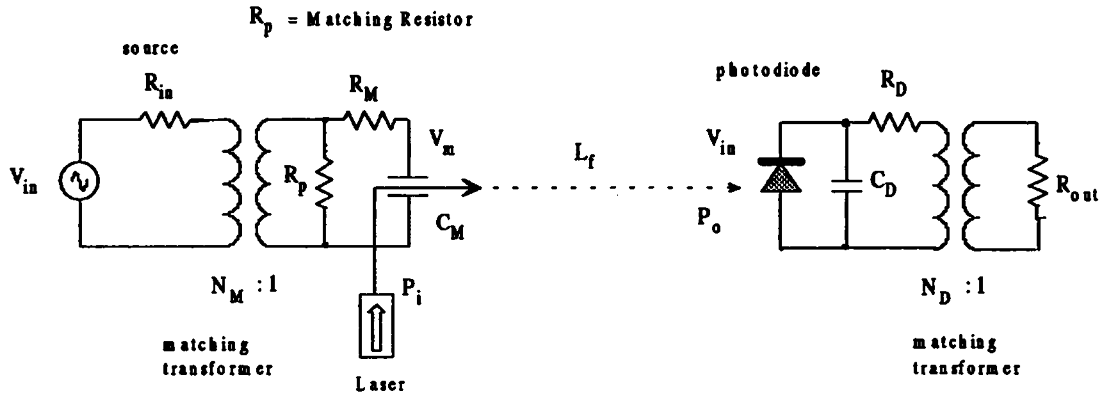


Fig 1 . Fiber transmitter /receiver equivalent cct

The large signal MZ modulator tranfer function

$$P_o := \frac{L_f \cdot P_i}{2} \cdot \left(1 + \cos\left(\pi \frac{V_m}{V_\pi}\right)\right)$$

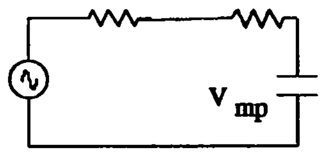
For small V_m about a nominal V_{bias}
the expression reduces to

$$P_o := \frac{L_f \cdot P_i}{2} \cdot \left(\frac{\pi \cdot V_m}{V_\pi}\right)$$

$$R_t := \frac{R_{in} \cdot R_p \cdot N_m^2}{R_{in} + R_p \cdot N_m^2}$$

Modulator Impedance

$$V_t := \frac{V_{in}}{N_m} \cdot \frac{R_p \cdot N_m^2}{\left(R_{in} + R_p \cdot N_m^2\right)}$$



$$N_m^2 \left(R_m + \frac{1}{SC_m}\right)$$

Fig 2. Fiber transmitter equivalent cct

V_{mp} is the drive voltage refered back to primary of transformer

$$V_{mp} := \left[\frac{\left(\frac{N_m^2}{SC_m}\right)}{N_m^2 \cdot R_m + \frac{N_m^2}{SC_m} + \left(\frac{R_{in} \cdot R_p \cdot N_m^2}{R_{in} + R_p \cdot N_m^2}\right)} \cdot \left(\frac{V_{in} \cdot R_p \cdot N_m^2}{R_{in} + R_p \cdot N_m^2}\right)\right]$$

$$V_{mp} := \frac{1}{S \cdot C_m \cdot R_m + 1 + \left(\frac{S \cdot C_m \cdot R_{in} \cdot R_p}{R_{in} + R_p \cdot N_m^2}\right)} \cdot \left(\frac{V_{in} \cdot R_p \cdot N_m^2}{R_{in} + R_p \cdot N_m^2}\right)$$

$$V_{mp} := \frac{1}{\left(S \cdot C_m R_m + S \cdot C_m \cdot \frac{R_{in} \cdot R_p}{R_{in} + R_p \cdot N_m^2}\right) + 1} \cdot \left(\frac{R_p \cdot N_m^2}{R_{in} + R_p \cdot N_m^2}\right) \cdot V_{in}$$

$$V_{mp} := \frac{1}{S \cdot C_m \left(R_m + \frac{R_{in} \cdot R_p}{R_{in} + R_p \cdot N_m^2}\right) + 1} \cdot \left(\frac{R_p \cdot N_m^2}{R_{in} + R_p \cdot N_m^2}\right) \cdot V_{in}$$

$$V_m := \frac{V_{mp}}{N_m}$$

$$V_m := \frac{1}{\left[S \cdot C_m \cdot \left(R_m + \frac{R_{in} \cdot R_p}{R_{in}\ R_p \cdot N_m^2}\right) + 1\right]} \cdot \left(\frac{R_p \cdot N_m}{R_{in} + R_p \cdot N_m^2}\right) \cdot V_{in}$$

$$V_m := \frac{1}{S \cdot C_m \cdot \left[\frac{R_m \cdot \left(R_{in} + N_m^2 \cdot R_p\right) + R_{in} \cdot R_p}{R_{in} + R_p \cdot N_m^2}\right] + 1} \cdot \left(\frac{R_p \cdot N_m}{R_{in} + R_p \cdot N_m^2}\right) \cdot V_{in}$$

The modulated optical power available at the photodetector is

$$P_o := \frac{L_f \cdot P_i}{2} \cdot \left(\frac{\pi \cdot V_{in}}{V_\pi}\right) \left(\frac{R_p \cdot N_m}{R_{in} + R_p \cdot N_m^2}\right) \left[\frac{1}{SC_m \cdot \left(\frac{R_m\left(R_{in} + N_m^2 \cdot R_p\right) + R_{in} \cdot R_p}{R_{in} + R_p \cdot N_m^2}\right) + 1}\right]$$

if the modulator impedance $\sqrt{R_m^2 + \frac{1}{(\omega C_m)^2}} \gg R_p$

also note that $R_m < R_p$

hence for a parallel match $R_{in} := N_m^2 \cdot R_p$

thus

$$P_o := \frac{L_f P_i}{2} \cdot \left(\frac{\pi \cdot V_{in}}{V_\pi}\right) \left(\frac{R_{in}}{2 \cdot R_{in} \cdot N_m}\right) \left(\frac{1}{S C_m \cdot R_{equ} + 1}\right)$$

where $R_{equ} := \frac{R_m \cdot \left(R_{in} + N_m^2 \cdot R_p\right) + R_{in} \cdot R_p}{R_{in} + R_p \cdot N_m^2}$

if C_m is very small ~ 10pf then the pole will be at GHz

below $f = \frac{1}{2 \cdot \pi \cdot C_m \cdot R_{equ}}$

$$P_o := \frac{L_f P_i}{2} \cdot \left(\frac{\pi \cdot V_{in}}{V_\pi}\right) \frac{1}{2 N_m}$$

$$P_o^{\,2} := \left(\frac{L_f \cdot P_i}{2} \cdot \frac{\pi \cdot V_{in}}{V_\pi} \right)^2 \cdot \frac{1}{4\,N_m^{\,2}}$$

For maximum power transfer the RF power $P_{in} := \dfrac{V_{in}^{\,2}}{4\,R_{in}}$

so the modulation sensitivity is $\dfrac{P_o^{\,2}}{P_{in}} := \left(\dfrac{L_f \cdot P_i \cdot \pi}{2 \cdot V_\pi} \right)^2 \cdot \dfrac{R_{in}}{N_m^{\,2}}$

simplified with $R_{in} := R_p \cdot N_m^{\,2}$ is

$$\frac{P_o^{\,2}}{P_{in}} := \left(\frac{L_f \cdot P_i \cdot \pi}{2 \cdot V_\pi} \right)^2 \cdot R_p$$

At the photodiode

$$I_{rout} := \left[\frac{\dfrac{1}{S \cdot C_d}}{\dfrac{1}{S \cdot C_d} \cdot \left(R_d + R_{out} \cdot N_d^{\,2} \right)} \right] \cdot I_d$$

Note that I_{rout} is the current after the transformer $N_d^{\,2}$

$$\eta := \frac{\Delta I_d}{\Delta P_o} \qquad \text{diode responsivity}$$

The RF output from the link is thus

$$P_{out} := I_{out}^2 \cdot R_{out}$$

$$P_{out} := \frac{I_d^2 \cdot R_{out} \cdot N_d^2}{1 + SC_d\left(R_d + R_{out} N_d^2\right)}$$

$$P_{out} := \frac{\eta^2 \cdot P_o^2 \cdot R_{out} \cdot N_d^2}{\left(1 + SC_d\left(R_d + R_{out} N_d^2\right)\right)^2}$$

hencce two poles exist at $f = \dfrac{1}{2\,\pi \cdot C_d\left(R_d + R_{out} N_d^2\right)}$

and 40dB/decade roll off

for $C_d := 0.5 \cdot pf$

$R_o := 50\,\Omega$

$R_d := 0$

$N_d := 1$

the pole roll off in response will be at f = 6.4GHz
when $N_d := 3$ the respnose is ~ 600MHz.
Thus for operation below the pole

$$P_{out} := \eta^2 \cdot P_o^2\, R_{out}\, N_d^2$$

and

$$\frac{P_{out}}{P_o^2} := \eta^2\, R_{out}\, N_d^2$$

The Link Gain is defined as

$$G := \frac{P_{out}}{P_{in}}$$

$$G := \left(\frac{P_o^{\,2}}{P_{in}}\right) \cdot \left(\frac{P_{out}}{P_o^{\,2}}\right)$$

$$G := \left(\frac{L_f \cdot P_i \cdot \pi}{2 \cdot V_\pi}\right)^2 \cdot R_p \cdot \left(\eta^2 \cdot P_o^{\,2} R_{out} N_d^{\,2}\right)$$

LINK GAIN is $$G := \left(\frac{L_f \cdot P_i \cdot \pi}{2 \cdot V_\pi}\right)^2 \cdot \eta^2 R_p \cdot R_{out} N_d^{\,2}$$

SYSTEM TESTS NOVEMBER 98

VLA to PIE TOWN SYSTEM TESTING

9/21/98 01:29 PM rjb

Upon completion of various phases of sub assembly and module construction appropriate bench tests are performed to assure the basic item specifications are met. Naturally, without the actual VLA and PT antennas these tests are limited.

The next process is to integrate the completed module hardware into 'real-time' VLA and PT systems to verify system performance criteria.

This document details 8 specific levels of system integration tests. Each successive test building on the knowledge and confidence of the previous test. In this way the number of potentially time consuming system problems in any one operation will be minimized and solved separately.

The following is a list of *potential trouble areas.*

1. Monitor Control System operation via new data link/software
2. VLA waveguide timing /synchronization
3. Overun of Data Invalid corrupting correlated data
4. Fringe Rotation
5. Control of IF center frequencies.
6. Maintaining SSB conversion sense compatibility between sites
7. Drift between MLO's at each site and measurement of same.
8. Maintaining integrity of Analog IF transmission
9. Setting required expanded delays.
10. Maintaining adequate dynamic range in the presence of strong interference.

To assist in the initial system tests and minimize the decorrelation effects caused by item (3) above narrow band IF filters eg. 5.75MHz will be set in the T4C Baseband Filter module. The increased SNR of 10dB will be of benefit as well in addressing item(10).

Test 1. CHECK ANALOG TRANSMISSION on 104km SMF and NEW DELAY CARDS

The IF outputs A,B,C,D from antenna X T2 IF Combiner is severed from the next stage T3 Baseband Converter and the 104km SMF link positioned in series between the two Modules. The antenna X round trip phase measurement system will work unaffected. The 104km link will be given a few hours warm up time in the air conditioned D rack environment prior to use.
Modified delay cards will need to be installed on antennas other than antenna X channels. Because of the close proximity of antenna X to other antennas, as opposed to PT, the values of delay will be large regardless of sky position (typ 400μS).

Test 2. CHECK PT CONVERSION RACK CENTER FREQUENCY and DCS

Antenna X will be operating in normal observing mode as 1 of 26 antennas. The 27th antenna (5 West) is offline and it's Central Buffer connected to the PT rack Antenna Buffer via a 0 uS delay, zero dispersion, adjustable optically attenuated digital link. An additional mixer stage (made from modifying the T201A converter module prototype) will be added to the PT conversion. The PT L7 ch A will operate with no phase rotation. PT L6 ch C will be used to supply the additional mixer LO used to convert the 1325 MHz ch A IF to nominal VLBA 500-1000MHz cf.
Other phase stable synthesizers may be used for this task but must be tunable in steps of 100KHz such that the 10.1MHz offsets are maintained.
Delay modifications are not required. IF transmission to the Antenna X IF input T3 can be via a short length of RG223 coaxial line.

Test 3. DCS with 506uS DELAY LINE

As per test 2 but 104km SMF is used in the DCS path. (506µS delay).
Delay card modifications are not required for this test.

Test 4. CHECK PT CONVERSION RACK PHASE ROTATION

As per test 3 but the task of phase rotation will be shifted from the antenna X L7 to the L7 (A,C) located in the PT conversion rack.
The L7 (B,D) will not be phase rotated and used as a stable 10.1MHz offset input to the L6 (C) synthesizer.
The software routine which sets the antenna X L7 phase rotation will need to pick up the co-ordinates of the array phase center to disable it's phase rotation . Servo control and the delay setting algorithms will use the real co-ordinate values as per normal.

Test 5. CHECK ANALOG and DCS path with FIBER OPTICS.

This test adds Fiber Optics to the analog path of test 4.
For this test the 104km test spool will be broken into two 52km spools and optical attenuation added to each spool . In this way dispersion and optical budgets are approximated.
The 253µS delay introduced to the IF path it will be desirable to use modified delay cards to all antennas that will correlate with antenna X.
If antenna X is located close to the correlator and the 'correlating' antennas located at extremes of the Y it would be possible to observe half sky regions with standard delay cards of 164µS max

Test 6. FIRST FRINGES

The PT conversion rack will be installed at PT as per block diagram B12625B001 Rev 2.
Two fibers will provide the interconnect back to the VLA rather than use more complex optical multiplexing. The lowest loss fiber will be used for the analog transmission while the second fiber will use optical circulators to provide bi-directional capability.
IF transmission will be limited to Ch A and the 1200MHz reference tone for the VLA roundtrip phase measurement system.
It is envisioned that 3 or 4 antennas will have expanded delay capability on ch A providing good cross product information.

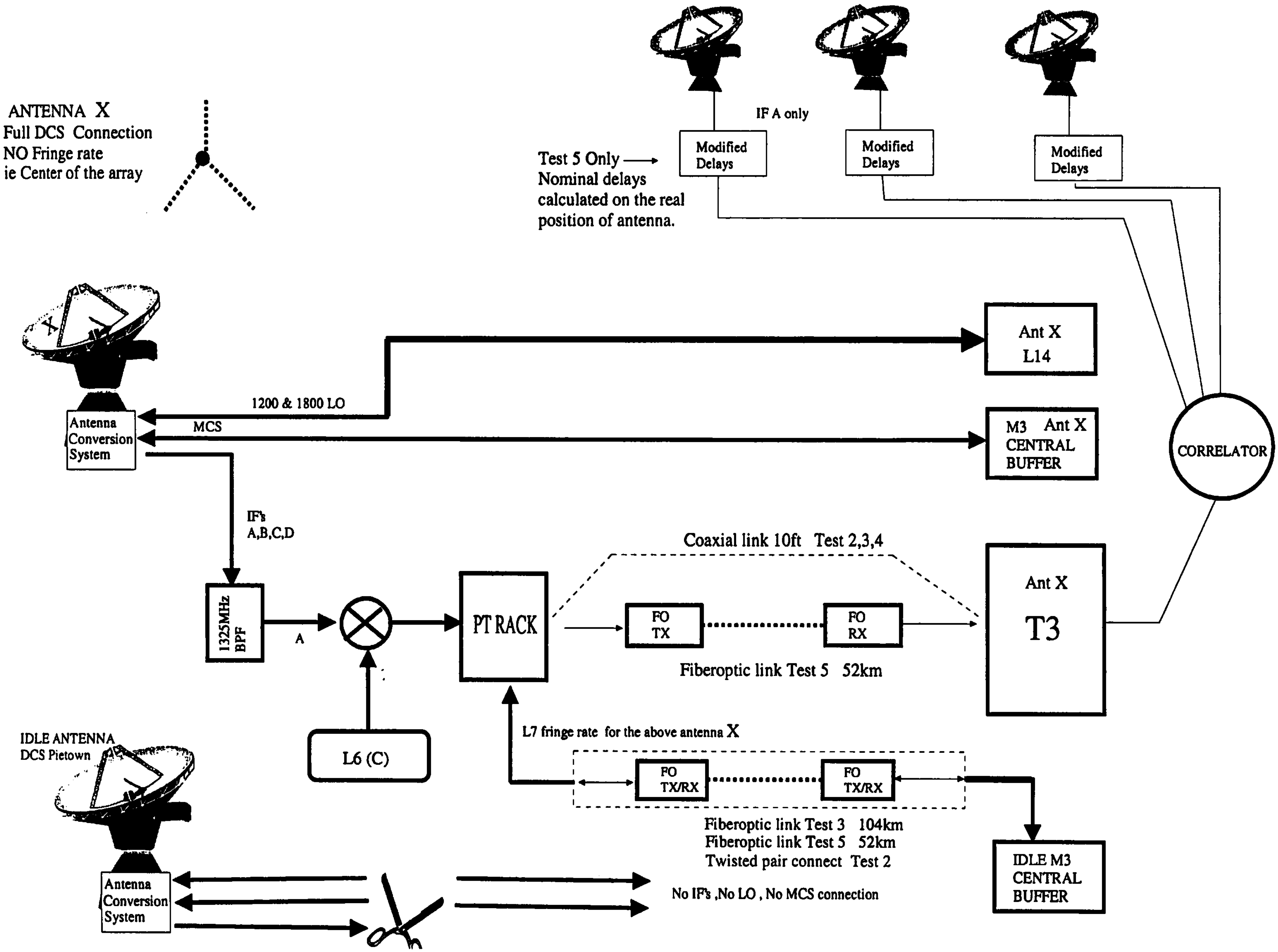
Test 7. 4 IF TESTS SELECT BASELINES.

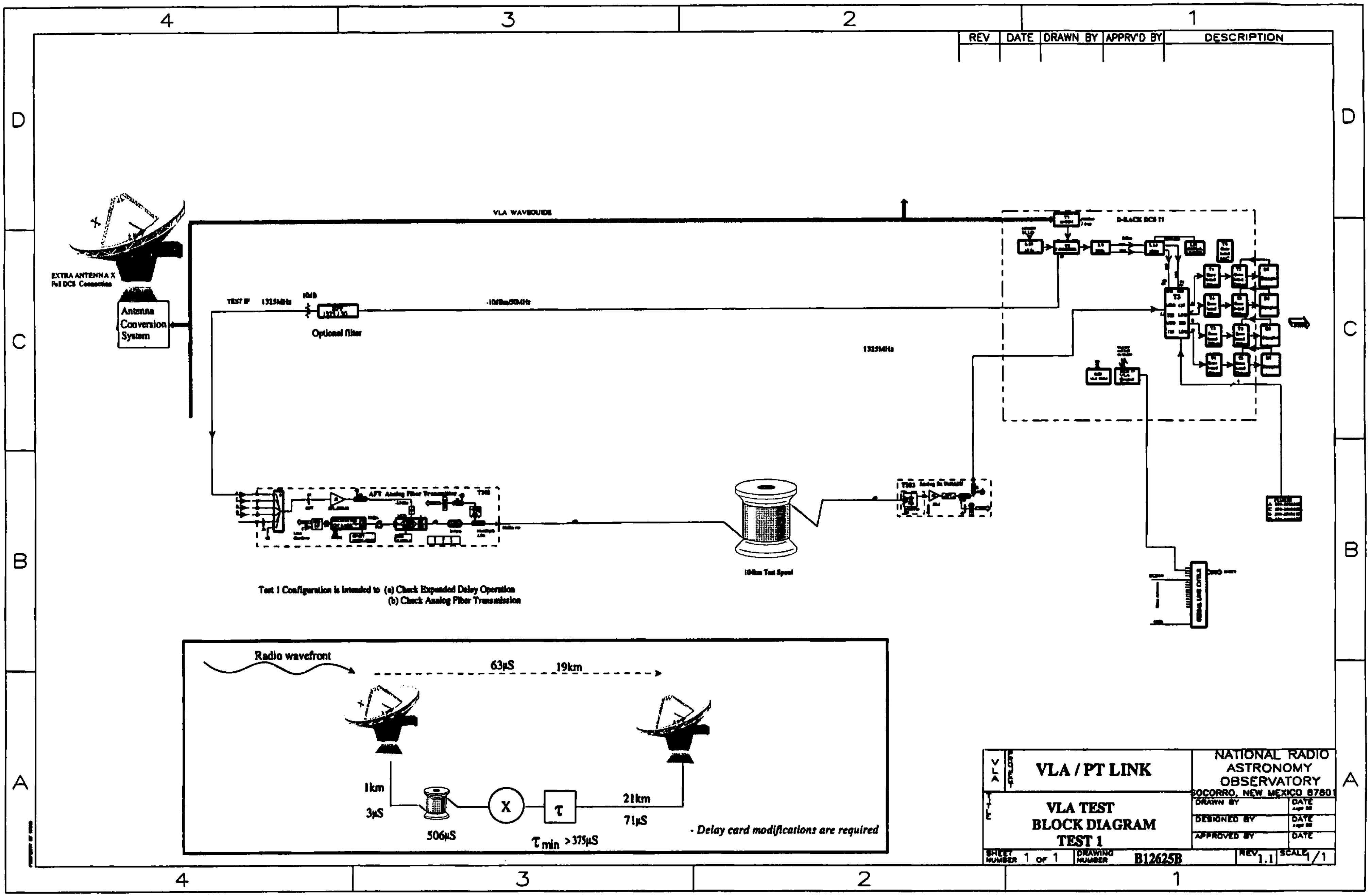
As per test 6 but with all 4 IF channels.
A considerable number of delay cards will need to be installed . At least 4 times the number of test 6 .

Test8. 4 IF TESTS ALL BASELINES.

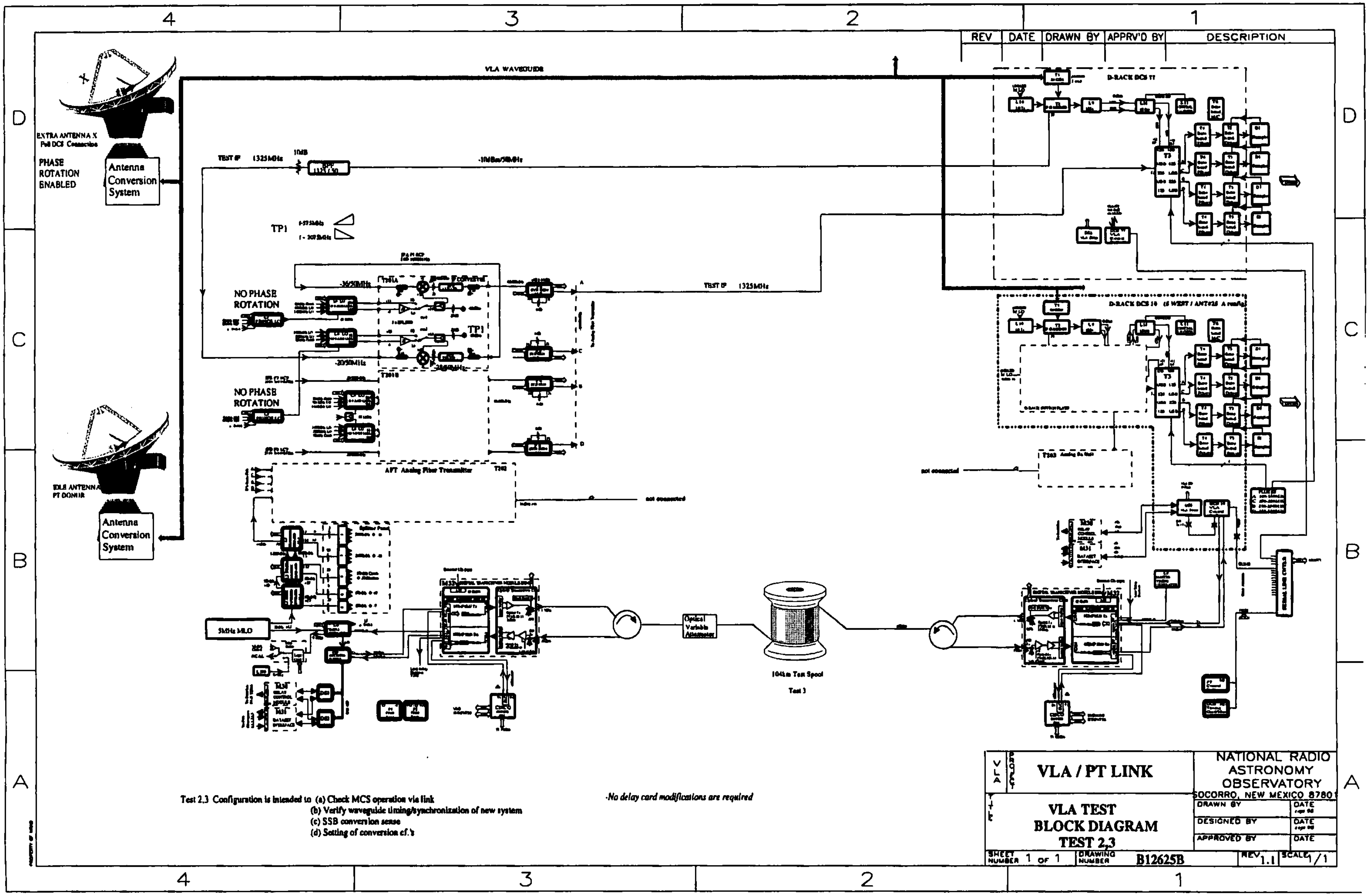
All 108 modified delay cards installed.

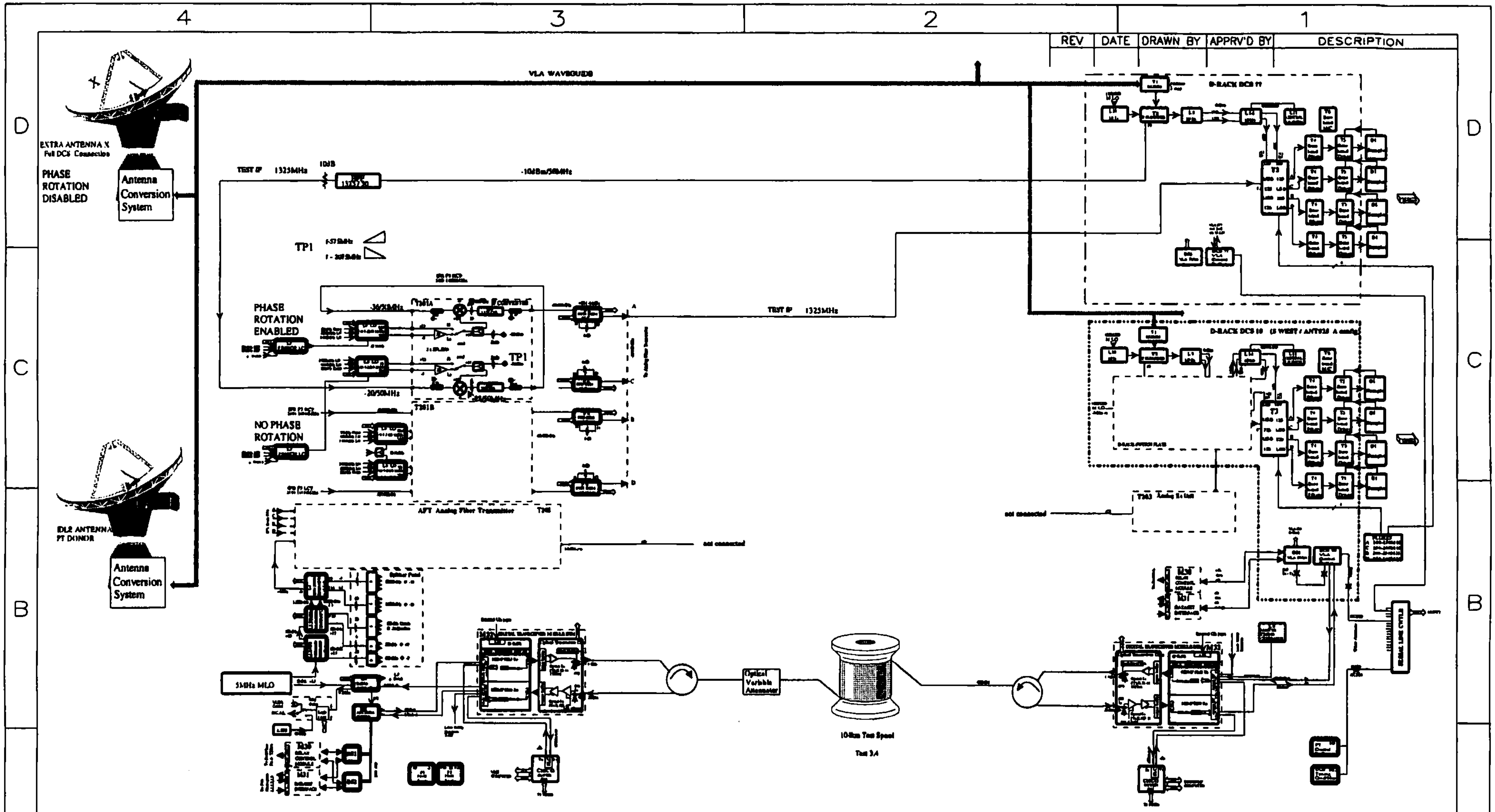
OVERVIEW of TEST SCHEME PT/VLA LINK ...(TESTS 2,3,4,5)





REV
DATE
DRAWN BY
APPRV'D BY
DESCRIPTION
VLA WAVEGUIDE
EXTRA ANTENNA X
Antenna Conversion System
TEST IF 1325MHz
Optional filter
1325MHz
10km Test Spool
Test 1 Configuration is intended to (a) Check Expanded Delay Operation
(b) Check Analog Fiber Transmission
Radio wavefront
63µS
19km
1km
3µS
506µS
X
τ
21km
71µS
τmin >375µS
- Delay card modifications are required
VLA / PT LINK
NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO 87801
VLA TEST
BLOCK DIAGRAM
TEST 1
DRAWN BY
DATE
DESIGNED BY
DATE
APPROVED BY
DATE
SHEET NUMBER 1 OF 1
DRAWING NUMBER B12625B
REV 1.1
SCALE 1/1


VLA WAVEGUIDE
EXTRA ANTENNA X
PHASE ROTATION ENABLED
Antenna Conversion System
IDLE ANTENNA
Antenna Conversion System
TEST IF 1325MHz
TP1
NO PHASE ROTATION
NO PHASE ROTATION
TEST IF 1325MHz
AFT Analog Fiber Transmitter
not connected
not connected
5MHz MLO
Optical Variable Attenuator
104km Test Spool
Test 3
REV
DATE
DRAWN BY
APPRV'D BY
DESCRIPTION
Test 2.3 Configuration is intended to (a) Check MCS operation via link
(b) Verify waveguide timing/synchronization of new system
(c) SSB conversion sense
(d) Setting of conversion cf.'s
-No delay card modifications are required
VLA PROJECT
VLA / PT LINK
NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO 8780
TITLE
VLA TEST BLOCK DIAGRAM TEST 2,3
DRAWN BY
DATE
DESIGNED BY
DATE
APPROVED BY
DATE
SHEET NUMBER 1 OF 1
DRAWING NUMBER B12625B
REV 1.1
SCALE 1/1

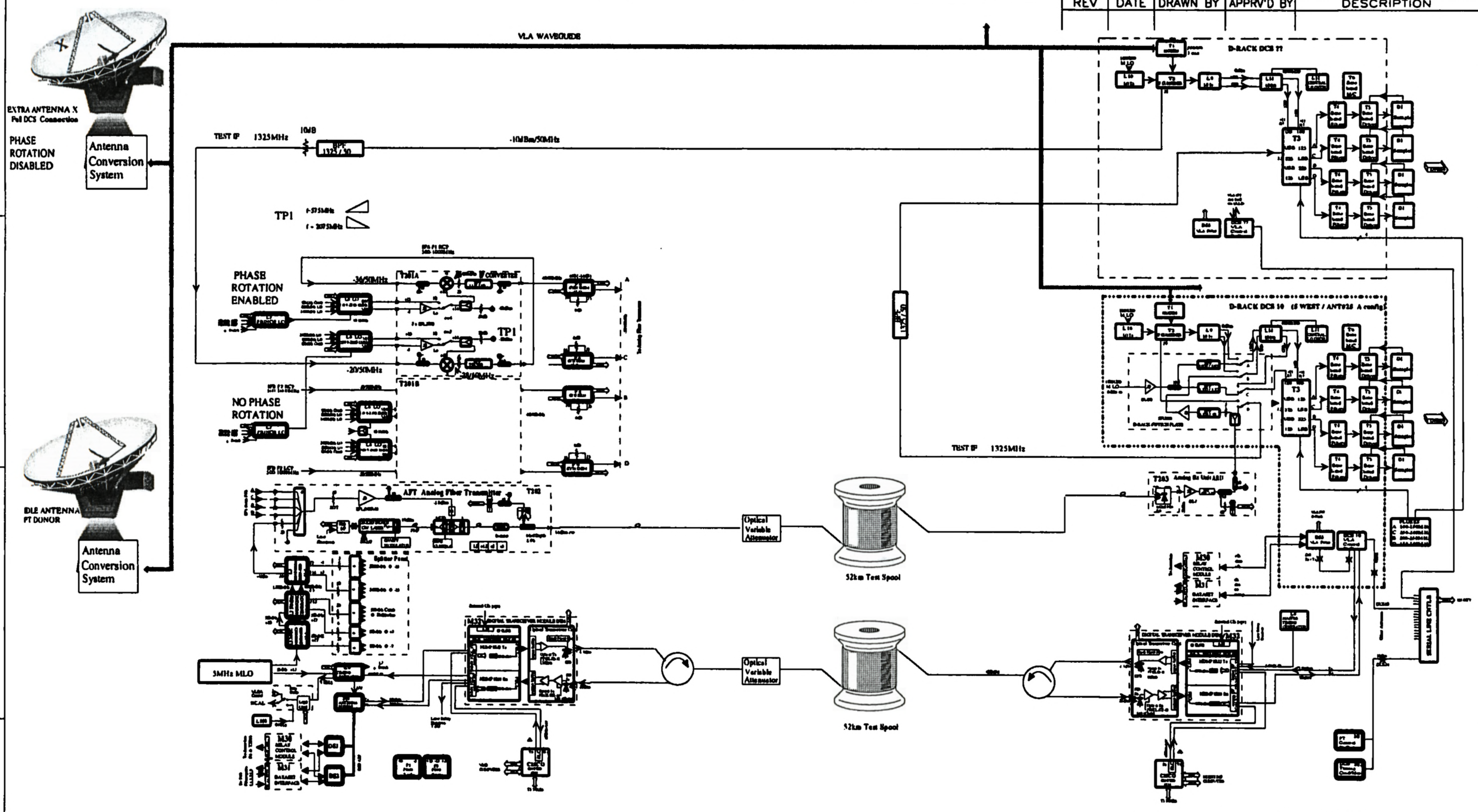


REV	DATE	DRAWN BY	APPR'V'D BY	DESCRIPTION

Test 4 Configuration is intended to (a) Check MCS operation via link
(b) Verify waveguide timing/synchronization of new system
(c) Check Fringe rotation an control of L7's
(d) SSB conversion sense
(e) Setting of conversion cf.'s

-No delay card modifications are required

VLA PROJECT: VLA / PT LINK		NATIONAL RADIO ASTRONOMY OBSERVATORY SOCORRO, NEW MEXICO 87801
TITLE: VLA TEST BLOCK DIAGRAM TEST 4	DRAWN BY	DATE
	DESIGNED BY	DATE
	APPROVED BY	DATE
SHEET NUMBER 1 OF 1	DRAWING NUMBER B12625B	REV 1.1 SCALE 1/1



Test 5 Configuration is intended to (a) Check MCS operation via link
(b) Verify waveguide timing/synchronization of new system
(c) Check Fringe rotation an control of L7's
(d) SSB conversion sense
(e) Setting of conversion cf.'s
(f) Check modified delay card operation

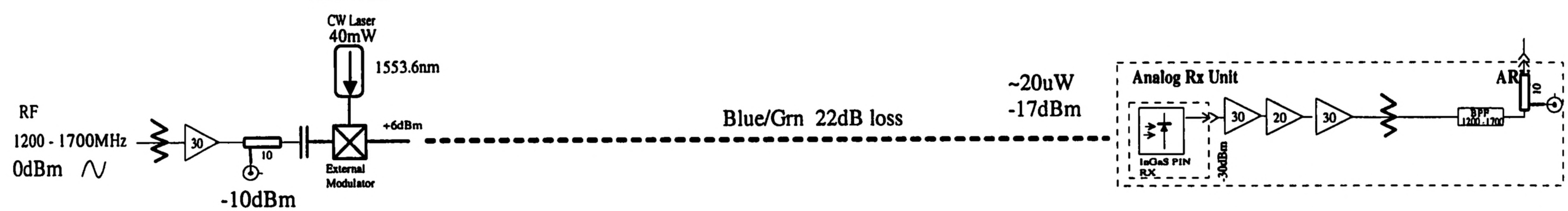
- Delay card modifications are required on other antennas

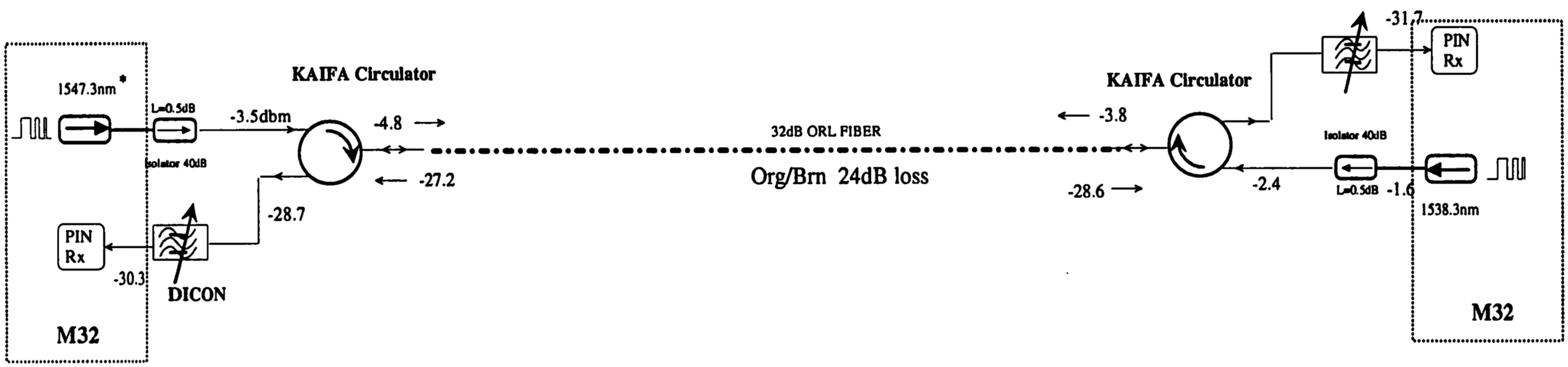
REV	DATE	DRAWN BY	APPRV'D BY	DESCRIPTION

VLA PROJECT: **VLA / PT LINK**	NATIONAL RADIO ASTRONOMY OBSERVATORY SOCORRO, NEW MEXICO 87801
TITLE: **VLA TEST BLOCK DIAGRAM TEST 5**	DRAWN BY — DATE sept 98 DESIGNED BY — DATE sept 98 APPROVED BY — DATE
SHEET NUMBER 1 OF 1 — DRAWING NUMBER B12625B	REV 1.1 — SCALE 1/1

Arrayproto FO. drw

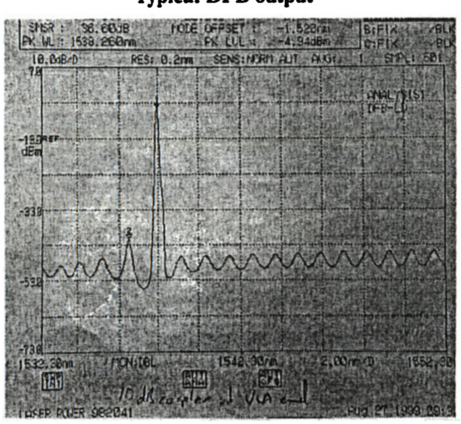
A- Array Prototype System Tests 2IF (A,C) 2 Fiber Implementation
September 99



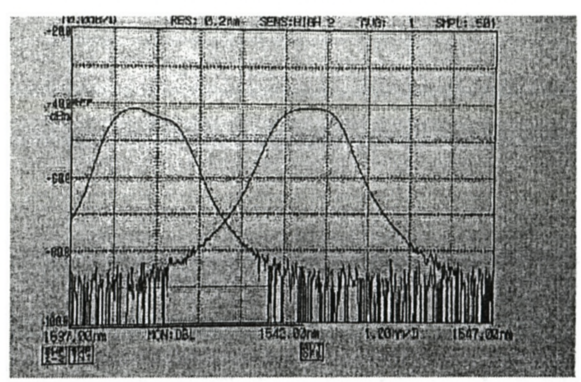


* 1542.42 also used

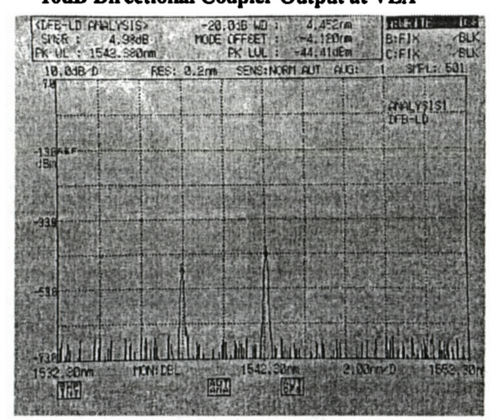
Typical DFB output



MTF -1550-0.8 -FC/APC-2P series tuneable filters



10dB Directional Coupler Output at VLA



MISCELLANEOUS

Optical Fiber

Standard Single-Mode Fiber

Optical Specifications

Typical Attenuation Cell (uncabled):
[< 0.35 / 0.40] dB/Km @ 1310 nm
[< 0.25 / 0.30] dB/Km @ 1550 nm

Attenuation Uniformity:
No point discontinuity greater than 0.1 dB at 1310 nm and 1550 nm.

Attenuation at 1383 nm: 2.0 dB/Km maximum

Attenuation vs. Wavelength:
Maximum attenuation change over the window.

Wavelength (nm)	Attenuation (dB/Km)
1285 - 1310	< 0.035
1330 - 1310	< 0.03
1525 - 1550	< 0.03
1575 - 1550	< 0.03

Attenuation with Bending:

100 turns around 75mm diameter	≤ 0.05 dB at 1310 nm ≤ 0.1 dB at 1550 nm
100 turns around 60mm diameter	≤ 0.5 dB at 1580 nm
1 turn around 32mm diameter	≤ 0.1 dB at 1550 nm
Cutoff Wavelength (cabled):	≤ 1260 nm
Zero Dispersion Wavelength:	1310 ±10 nm
Zero Dispersion Slope:	< 0.092 ps/nm² • Km
PMD:	≤ 0.5 ps/√km

Dimensional Specifications

Mode Field Diameter at 1310 nm:	9.0 ±0.5 µm
at 1550 nm:	10.2 ± 1 µm
Fiber Outside Diameter:	125 ±1.0 µm
Core Eccentricity:	≤ 0.8 µm
Fiber Non-Circularity:	< 1.0%
Core Non-Circularity:	< 10.0%
Coating Outside Diameter:	245 ± 10 µm
Coating/Clad Concentricity Error:	≤ 15 µm
Fiber Curl (deflection over 10 mm)	curl radius ≥ 2 meter ≤ 25 µm

Environmental Specifications

Temperature cycling performance: -60°C to +85°C
Attenuation increase ≤ 0.05 dB/Km at 1310nm and 1550 nm.

Typical Characterization Values

Numerical Aperture:	0.12
Nominal Zero Dispersion Wavelength:	1310 nm
Nominal Zero Dispersion Slope:	0.086 ps/nm² • Km
Effective Group Index:	1.4640 at 1310 nm 1.4645 at 1550 nm
Backscatter Coefficient:	-76.7dBm at 1310nm -81.7dBm at 1550nm
Typical Core Diameter:	8.8µm
Dynamic Tensile Strength (0.5 m gauge length) *Aged:	median ≥ 750 kpsi (5.26GN/m²)
Dynamic Fatigue, 2 Point Bend:	Nd = 22
Static Fatigue:	Ns ≥ 35 aged 85°C,85% RH
Max Dispersion: 1285-1330 nm	≤ 2.8 ps/nm • Km
1550 nm	≤ 18 ps/nm • Km

*Aged: 30 days at 85°C (185°F) and 85% relative humidity

Issued: 9/96 4M

Mechanical Specifications

Proof Test

The entire length of fiber is subjected to a tensile proof stress greater than 100 kpsi (0.69 GN/m²); 1% strain equivalent.

Dynamic Tensile Strength (0.5 meter gauge length)
Unaged: median ≥ 550 kpsi (3.8 GN/m²)
Aged*: median ≥ 440 kpsi (3.0 GN/m²)

Dynamic Fatigue, Tensile: N_d ≥ 20 unaged and aged*

Dynamic Fatigue, 2 Point Bend: N_d ≥ 20 unaged and aged*

Static Fatigue: N_s ≥ 20 aged at 85°C, 85% RH

Coating Strip Force: 2.0 lbf (8.9N) max, 0.3 lbf (1.3N) min.
- 23°C (73°F), 0°C (32°F) and 45°C (113°F)
- Aged*
- 14 days water immersion at 23°C (74°F)
- wasp spray exposure (Bellcore)

*Aged: 30 days at 85°C (185°F) and 85% relative humidity

Test Procedures

Alcatel uses the following test procedures in specifying and characterizing its optical fiber:

MECHANICAL	
EIA RS-455-28B	Dynamic Tensile Test
EIA RS-455-31C	Fiber Proof Test
EIA RS-455-33A	Cable Tensile Loading and Bending.
EIA RS-455-76	Dynamic Fatigue (with proposed FOTP modifications)
EIA RS-455-97	Static Fatigue
EIA RS-455-178A	Coating Strip Force
EIA RS-455-111	Fiber Curl
OPTICAL/GEOMETRICAL	
EIA RS-455-176	Fiber Geometry
EIA RS-455-173	Fiber Coating Geometry
EIA RS-455-59A	Point Discontinuities (OTDR)
EIA/TIA-455-60A	Fiber Length (OTDR)
EIA RS-455-61A	Attenuation Measurement (OTDR)
EIA RS-455-62A	Fiber Macrobend
EIA RS-455-78A	Attenuation Measurement (Cutback)
EIA RS-455-80A	Cutoff Wavelength (un-cabled)
EIA RS-455-167A	Mode Field Diameter
EIA RS-455-168A	Chromatic Dispersion
EIA/TIA-455-113	Polarization Mode Dispersion (PMD)
ENVIRONMENTAL	
EIA RS-455-3A	Temperature Cycling
EIA RS-455-73	Temperature/Humidity Cycling
EIA RS-455-75	Fluid Immersion

ALCATEL
TELECOMMUNICATIONS CABLE

P.O. Box 39
2512 Penny Road
Claremont, NC 28610-0039
(704) 459-9787 / 800-729-3737
email: marketing@ccm.uscable.alcatel.com

Optical Fiber
7669 Enon Drive
Roanoke, VA 24019
(540)265-0612/800-934-2379
email: fiber@ccm.uscable.alcatel.com

VLA
VLBA
MMA

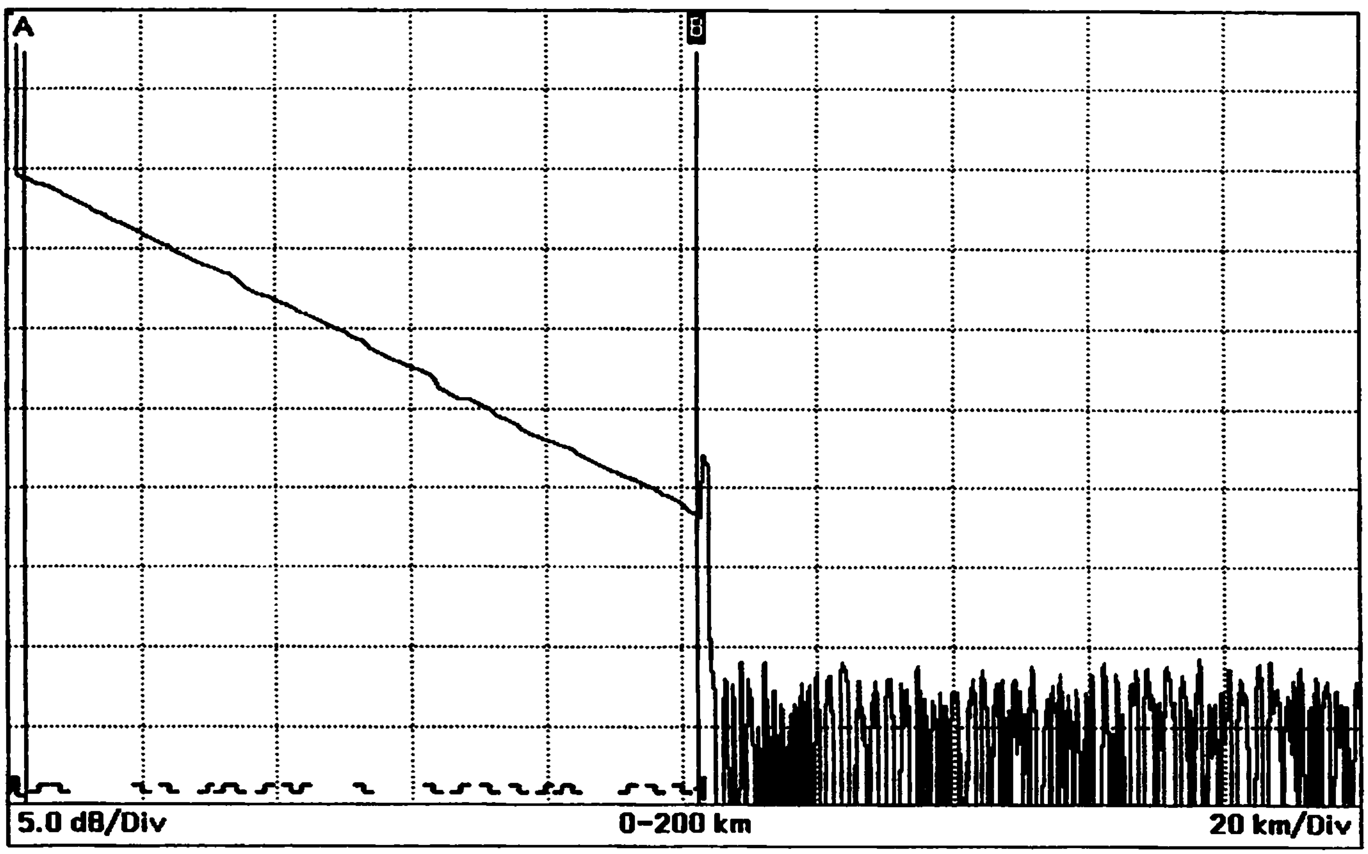
E6000A
OPTICAL TIME DOMAIN REFLECTOMETER

04/30/1998   10:50:51   **Page 1/2**

Trace: VLA3F.SOR   **Measurement Date: 04/24/1998 – 13:05:25**

Cable ID	: VLA/PT WNMT		
Fiber ID	: VLA-3-GREEN		(good line)
Orig. Loc.	: PIETOWN		in final system
	:		
Operator	: RJB		
Mainframe	: E6000A	DE37601133	3.3
Module	: E6003A	3617G00784	(single-mode)

Range:	0–200 km	**Optimize mode:**	dynamic
Pulsewidth:	10 µs	**Sampledistance:**	12.79 m
Wavelength:	1550 nm	**Averaging time:**	1:00
Scatter coefficient:	51.5 dB	**Refractive index:**	1.46450



VLA
VLBA
MMA

E6000A
OPTICAL TIME DOMAIN REFLECTOMETER

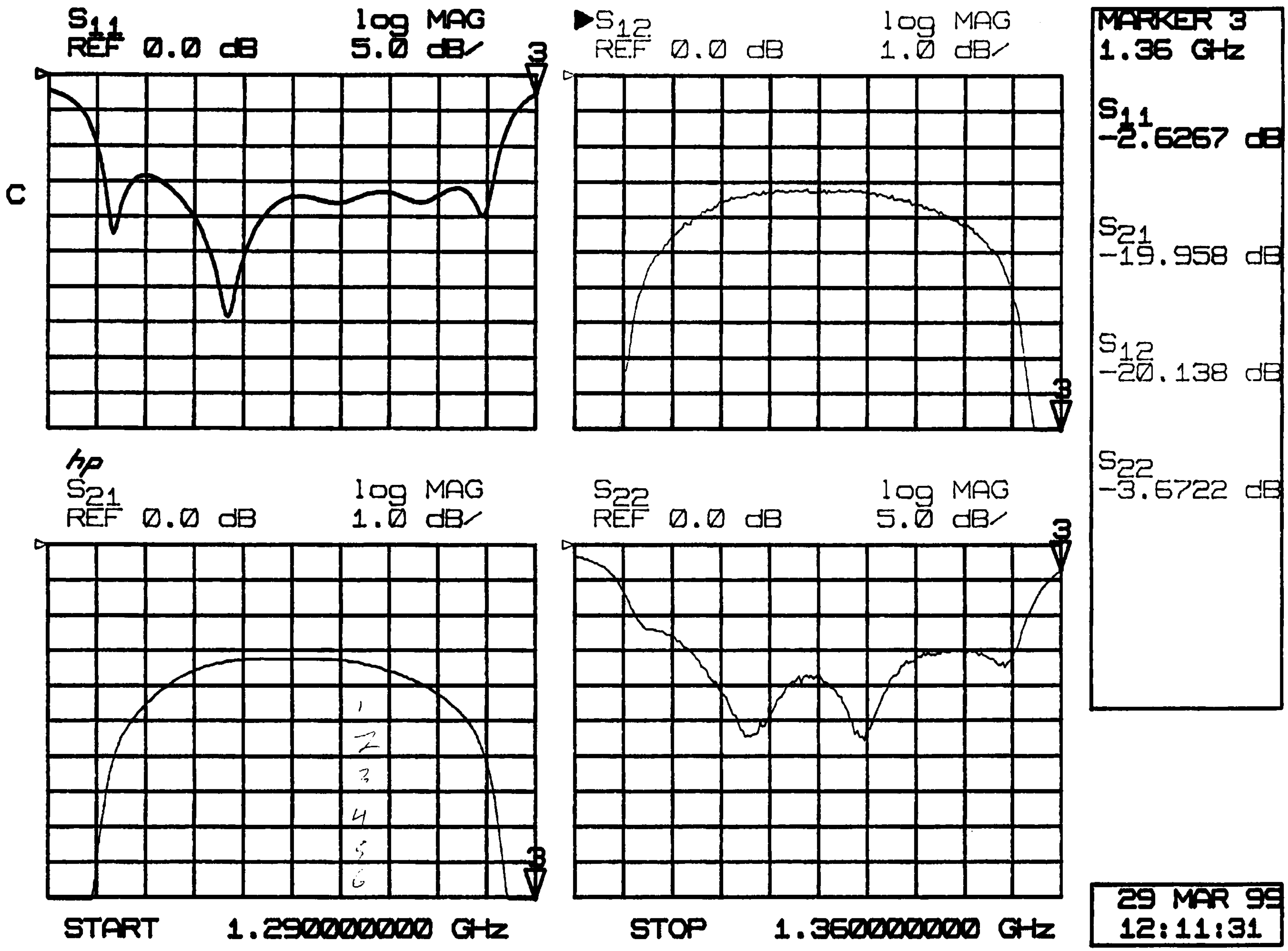
04/30/1998 12:21:02 Page 1/2

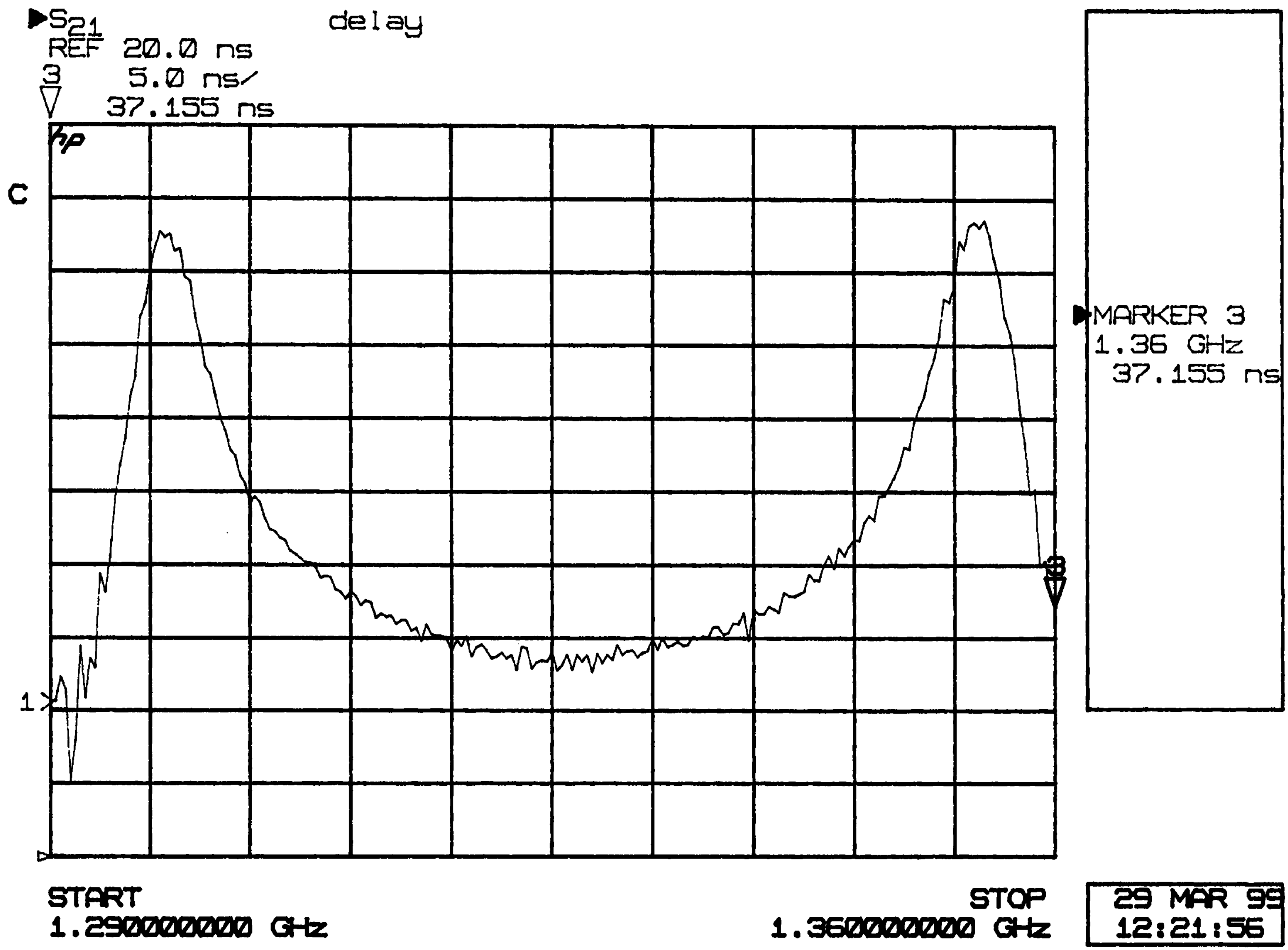
Trace: VLA4F.SOR	Measurement Date: 04/24/1998 - 13:13:15

Cable ID	: VLA/PT WNMT		
Fiber ID	: VLA-4-BROWN		
Orig. Loc.	: PIETOWN		
Term. Loc.	: VLA SIECOR BOX		
Operator	: RJB		
Mainframe	: E6000A	DE37601133	3.3
Module	: E6003A	3617G00784	(single-mode)

Range:	0-200 km	Optimize mode:	dynamic
Pulsewidth:	10 μs	Sampledistance:	12.79 m
Wavelength:	1550 nm	Averaging time:	1:00
Scatter coefficient:	51.5 dB	Refractive index:	1.46450

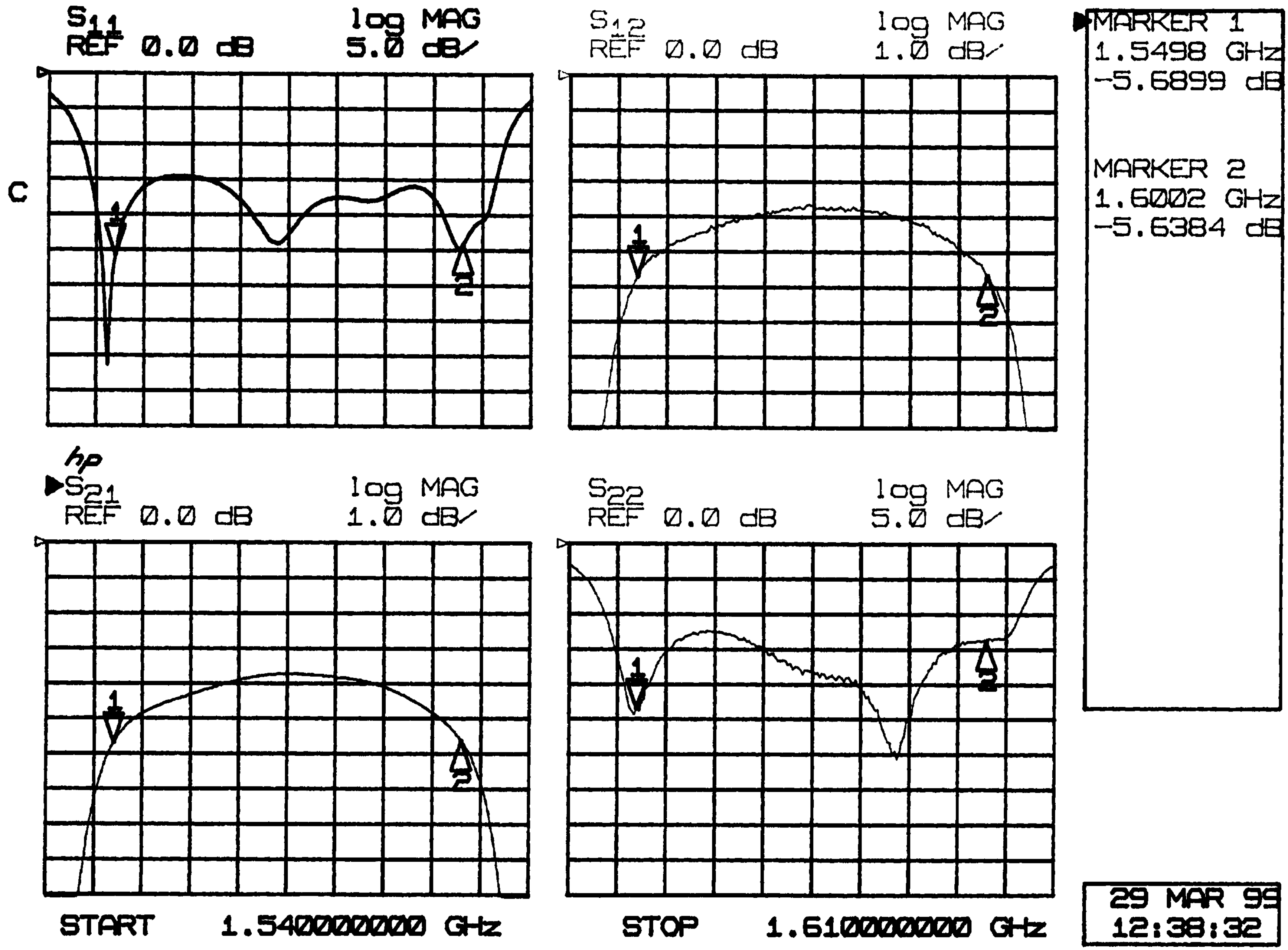
5.0 dB/Div 0-200 km 20 km/Div

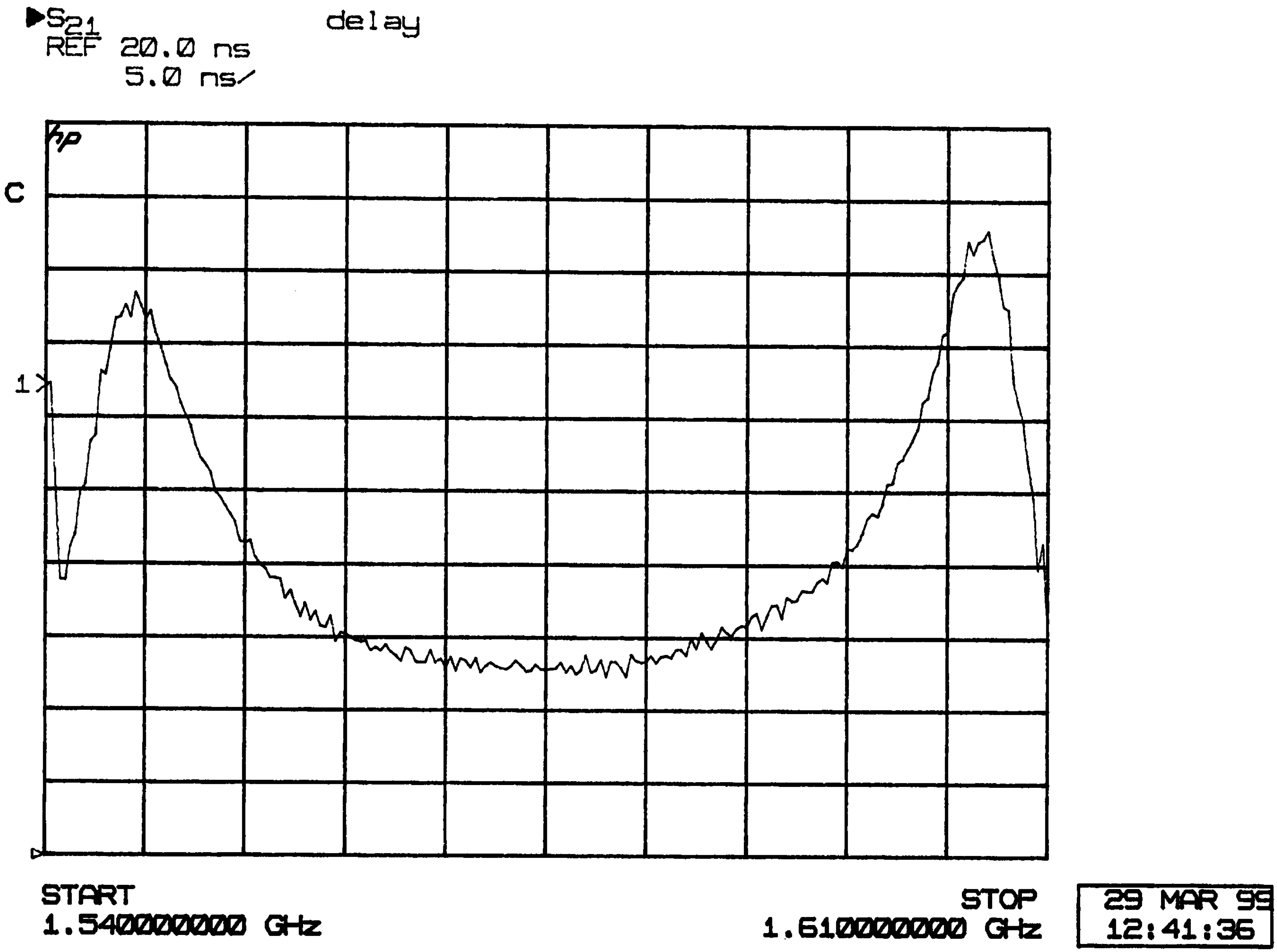

S11 REF 0.0 dB
log MAG 5.0 dB/
▶S12 REF 0.0 dB
log MAG 1.0 dB/
MARKER 3
1.36 GHz
S11
-2.6267 dB
S21
-19.958 dB
S12
-20.138 dB
S22
-3.6722 dB
C
hp
S21 REF 0.0 dB
log MAG 1.0 dB/
S22 REF 0.0 dB
log MAG 5.0 dB/
1
2
3
4
5
6
START 1.290000000 GHz
STOP 1.360000000 GHz
29 MAR 99
12:11:31



S21 delay
REF 20.0 ns
3 5.0 ns/
37.155 ns
hp
C
1
MARKER 3
1.36 GHz
37.155 ns
START
1.290000000 GHz
STOP
1.360000000 GHz
29 MAR 99
12:21:56

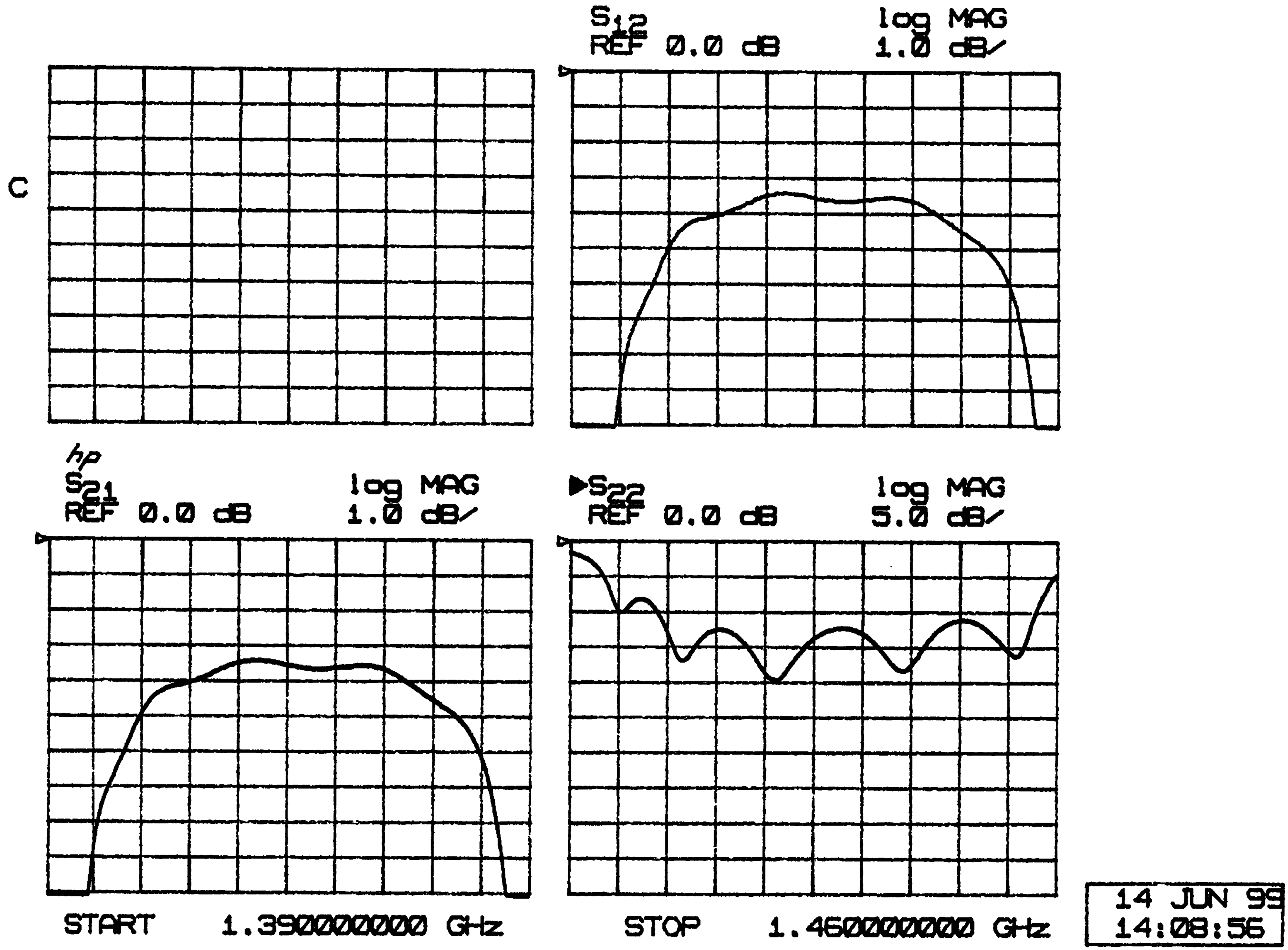
s/n 4195-1


S11
REF 0.0 dB
log MAG
5.0 dB/
C
S12
REF 0.0 dB
log MAG
1.0 dB/
MARKER 1
1.5498 GHz
-5.6899 dB
MARKER 2
1.6002 GHz
-5.6384 dB
hp
S21
REF 0.0 dB
log MAG
1.0 dB/
S22
REF 0.0 dB
log MAG
5.0 dB/
START 1.540000000 GHz
STOP 1.610000000 GHz
29 MAR 99
12:38:32

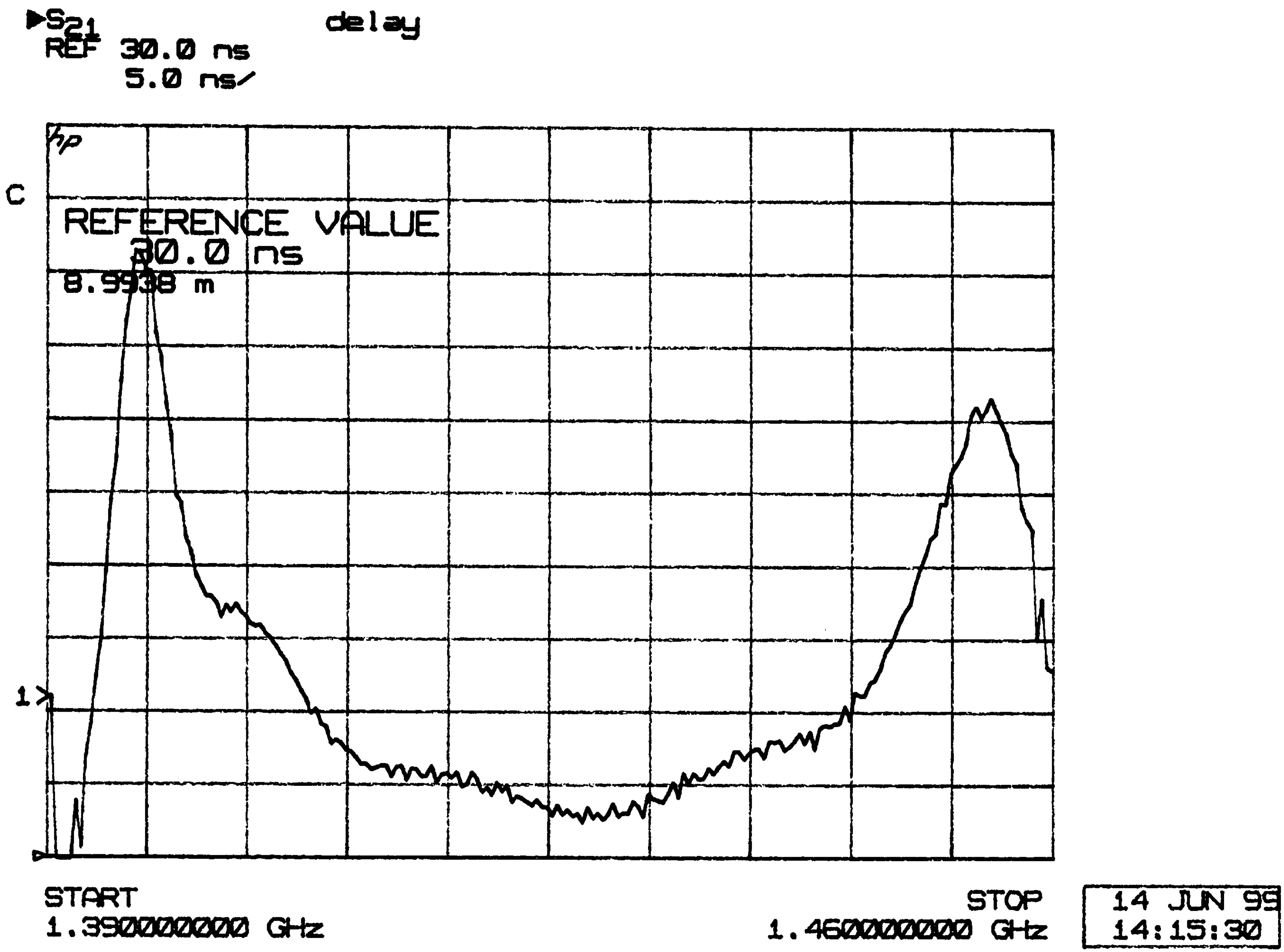


S21 delay
REF 20.0 ns
5.0 ns/
hp
C
1
START
1.540000000 GHz
STOP
1.610000000 GHz
29 MAR 99
12:41:36

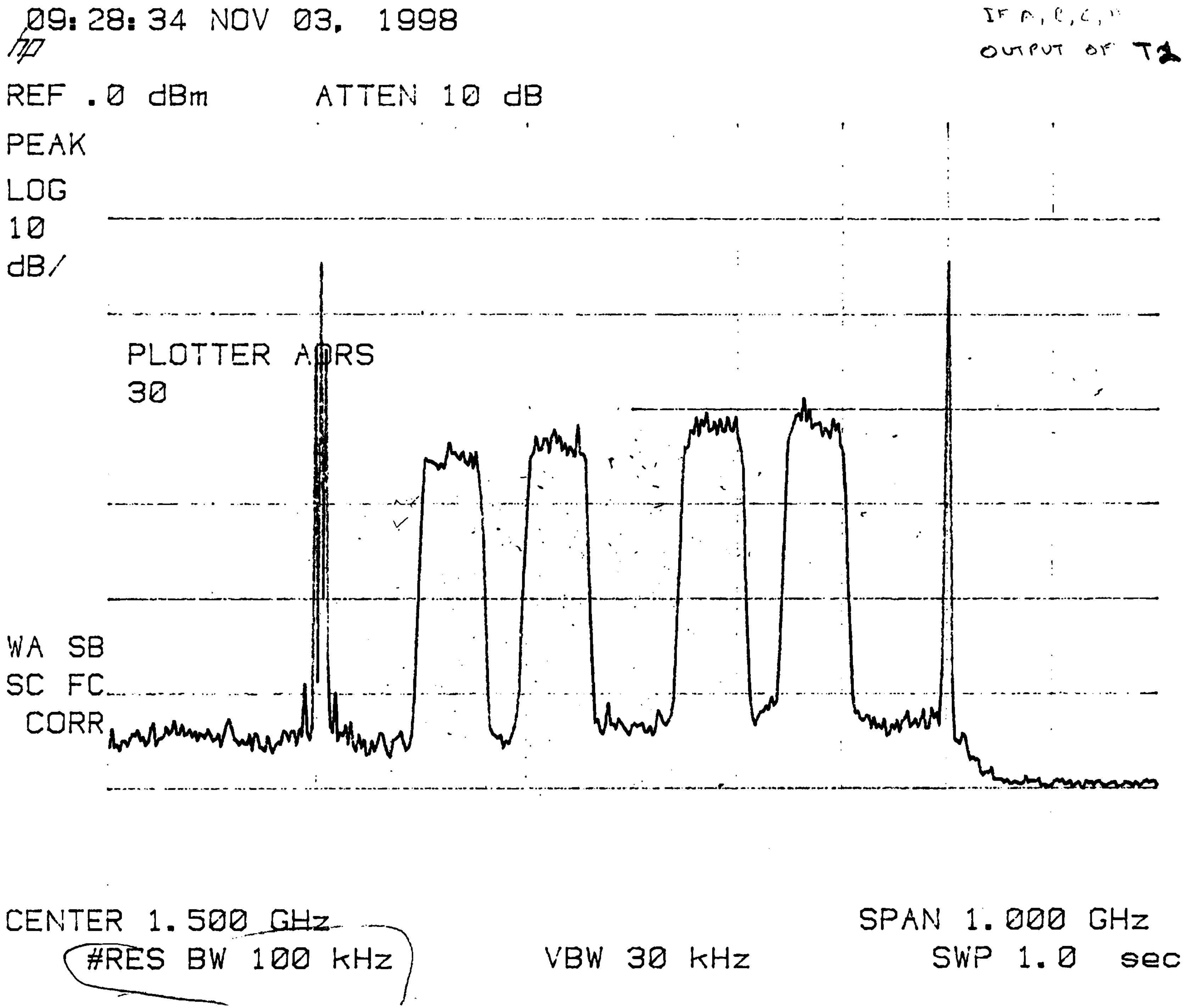
8012c - 1+25/50 - 0/0r
IF-B Pietown link



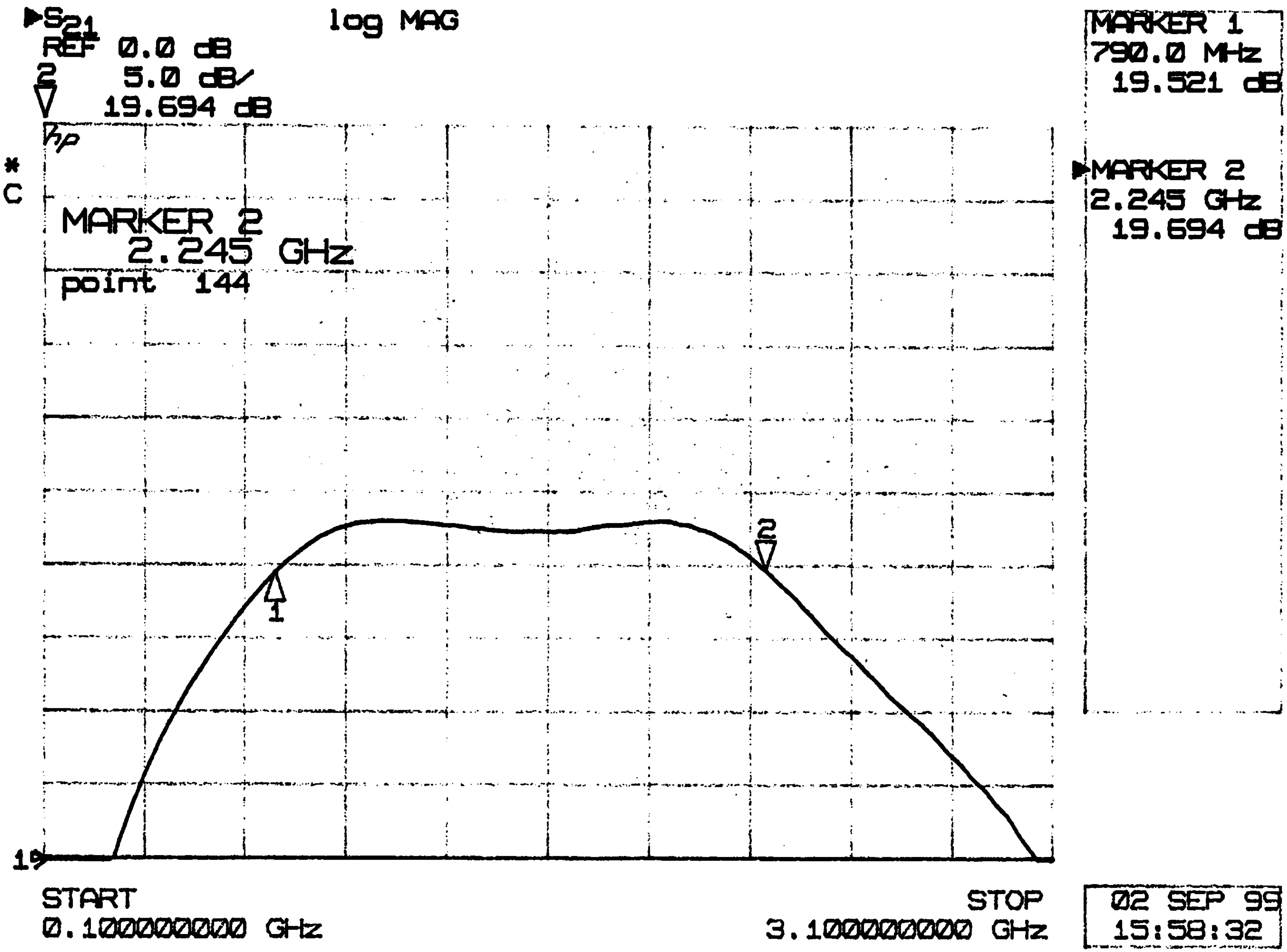
8B120 - 1425/50 - O/OP



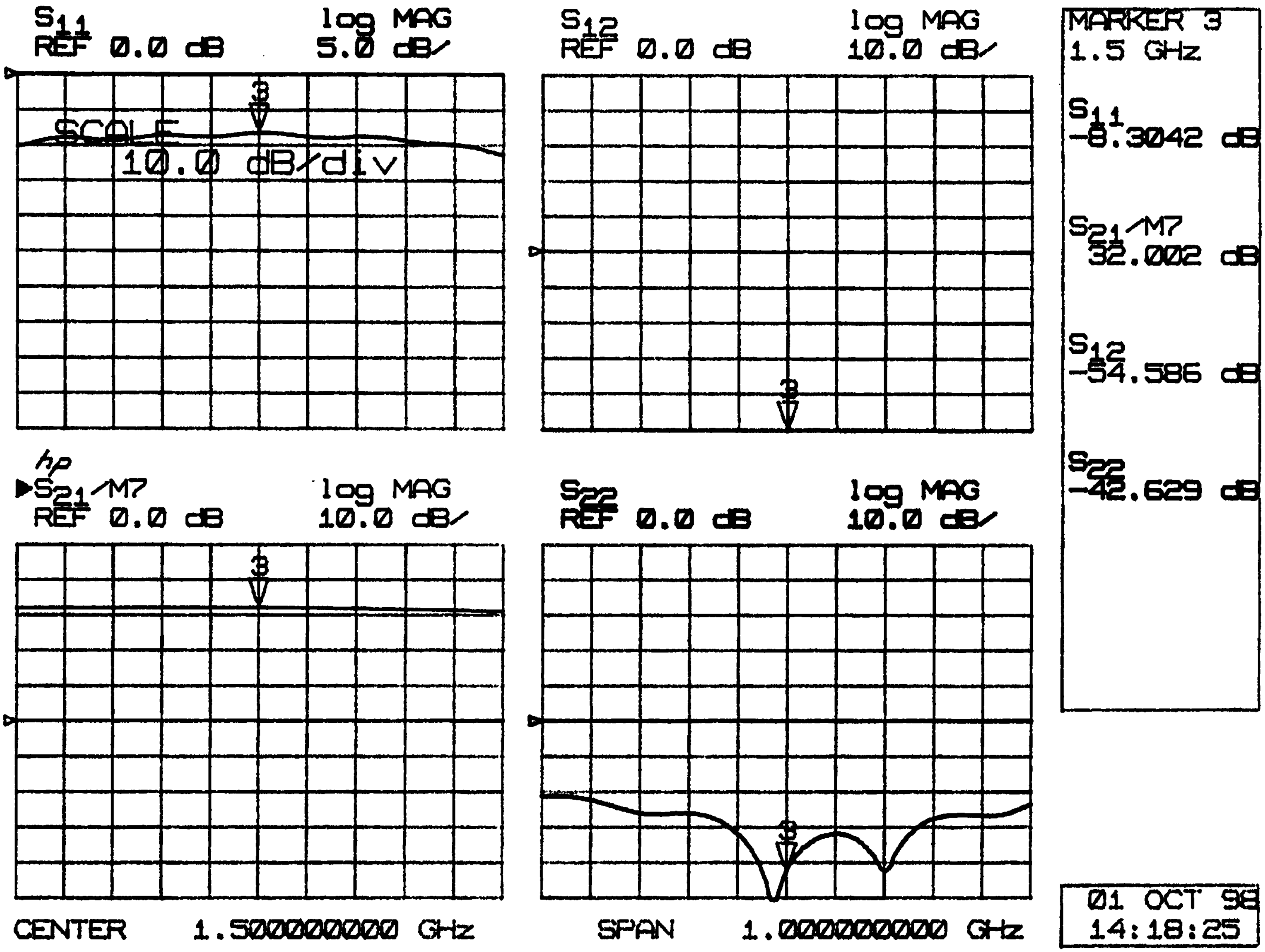
OUTPUT OF T2

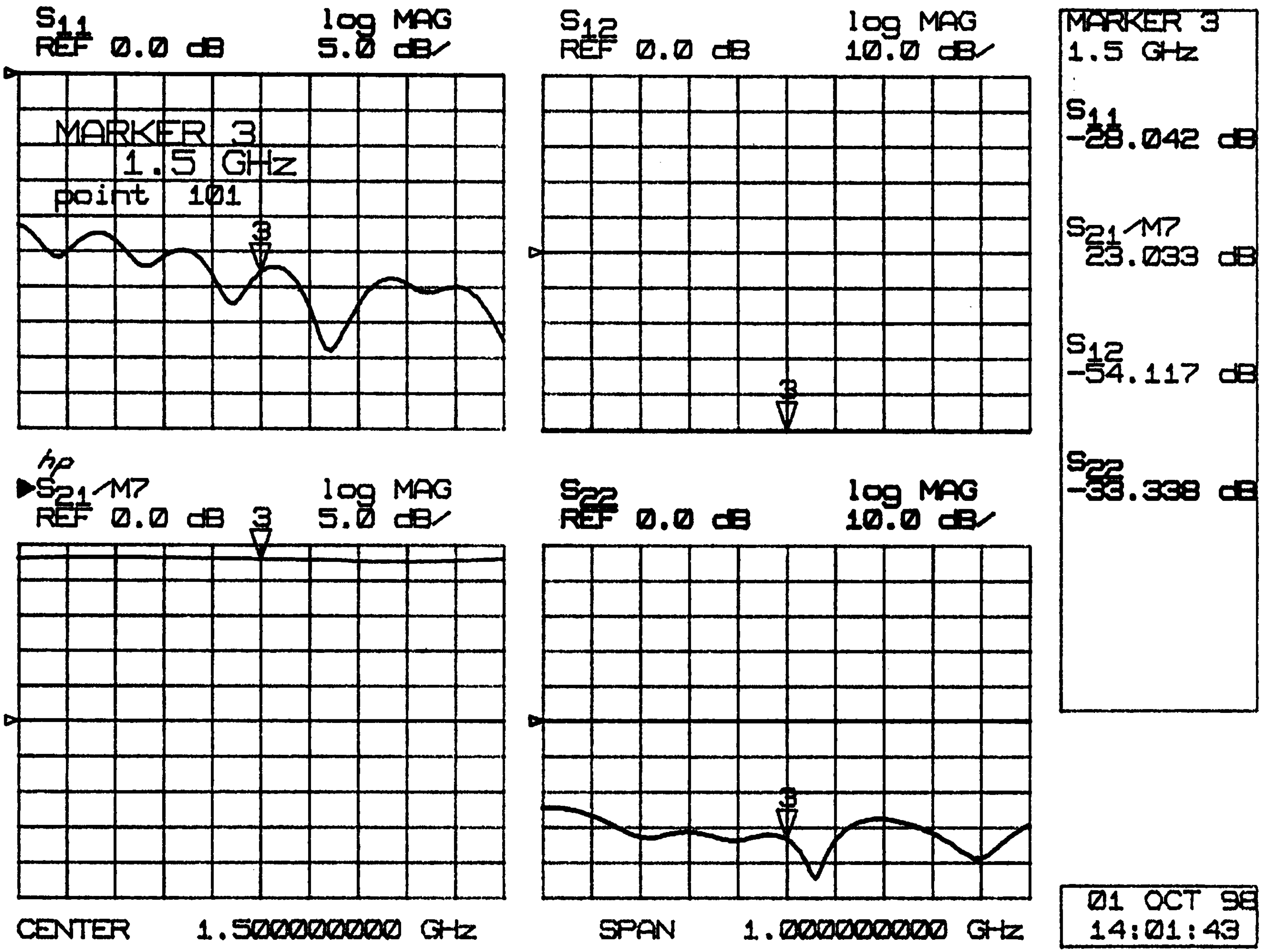

09:28:34 NOV 03, 1998
REF .0 dBm
ATTEN 10 dB
PEAK
LOG
10
dB/
PLOTTER ADRS
30
WA SB
SC FC
CORR
CENTER 1.500 GHz
#RES BW 100 kHz
VBW 30 kHz
SPAN 1.000 GHz
SWP 1.0 sec

ZEL-1217LN



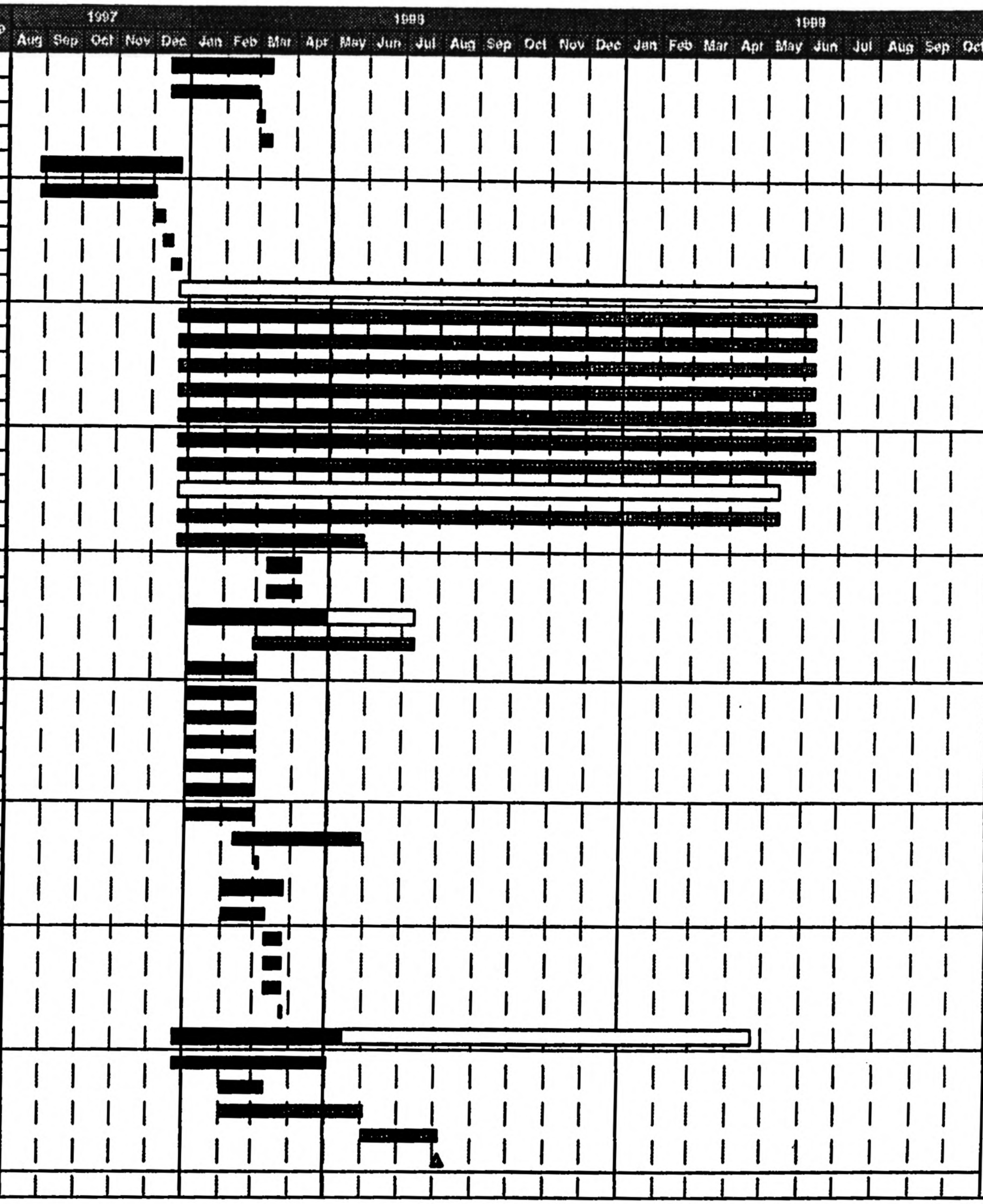
S21
log MAG
REF 0.0 dB
2
5.0 dB/
19.694 dB
hp
*
C
MARKER 2
2.245 GHz
point 144
1
2
1
MARKER 1
790.0 MHz
19.521 dB
MARKER 2
2.245 GHz
19.694 dB
START
0.100000000 GHz
STOP
3.100000000 GHz
02 SEP 99
15:58:32


S11 log MAG
REF 0.0 dB 5.0 dB/
SCALE
10.0 dB/div
S12 log MAG
REF 0.0 dB 10.0 dB/
hp
▶S21/M7 log MAG
REF 0.0 dB 10.0 dB/
S22 log MAG
REF 0.0 dB 10.0 dB/
MARKER 3
1.5 GHz
S11
-8.3042 dB
S21/M7
32.002 dB
S12
-54.586 dB
S22
-42.629 dB
01 OCT 98
14:18:25
CENTER 1.500000000 GHz
SPAN 1.000000000 GHz



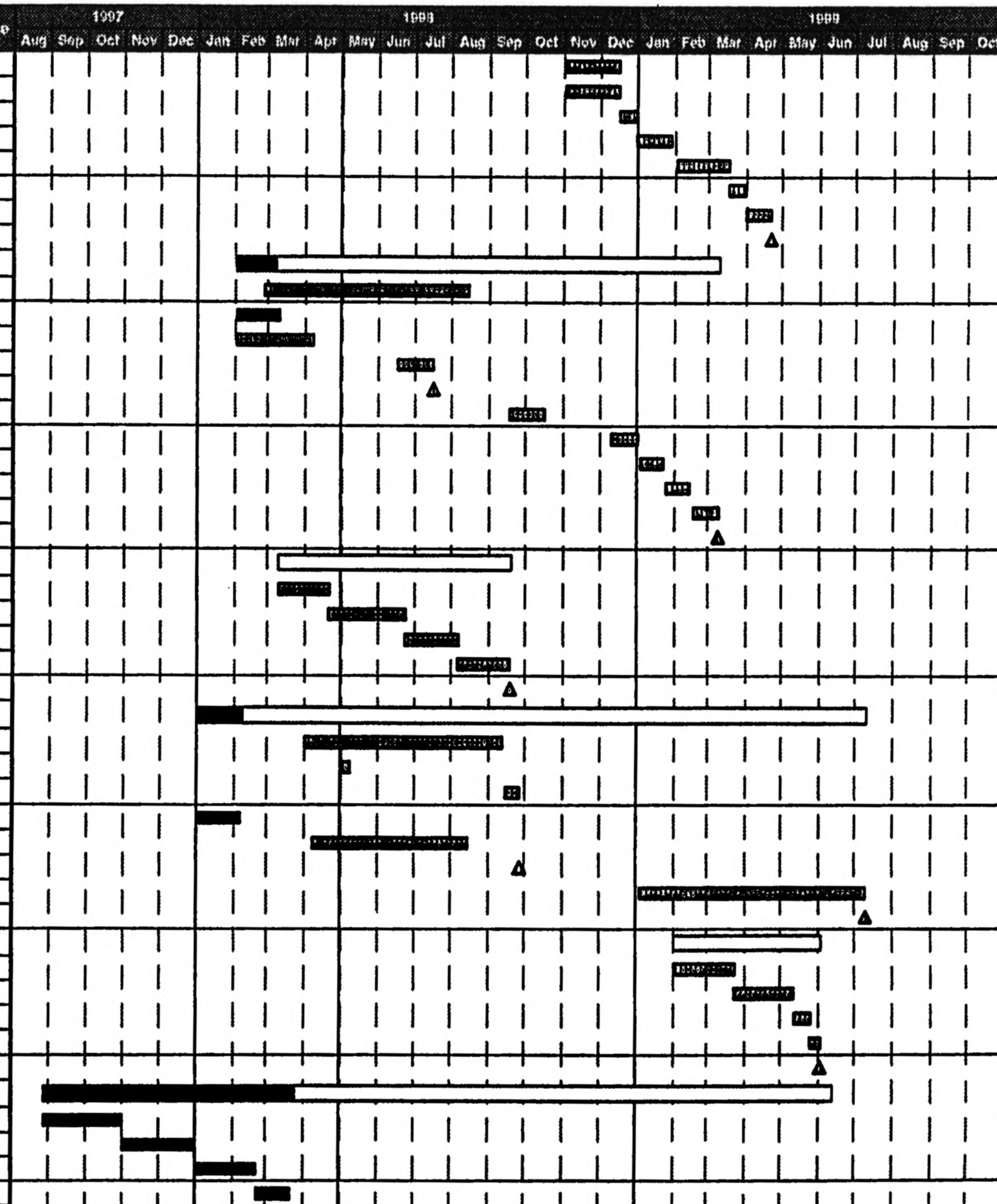
S11
REF 0.0 dB
log MAG
5.0 dB/
MARKER 3
1.5 GHz
point 101
S12
REF 0.0 dB
log MAG
10.0 dB/
hp
S21/M7
REF 0.0 dB
log MAG
5.0 dB/
S22
REF 0.0 dB
log MAG
10.0 dB/
MARKER 3
1.5 GHz
S11
-28.042 dB
S21/M7
23.033 dB
S12
-54.117 dB
S22
-33.338 dB
01 OCT 98
14:01:43
CENTER 1.500000000 GHz
SPAN 1.000000000 GHz

Task Name	Resources	Start Date	Duration	End Date
10 Revised Project Plan		**12/15/97**	**57.50d**	**3/9/98**
10.05 Prepare Project Plan	Campbell	12/15/97	50.00d	2/25/98
10.10 Review Poject Plan	Ulvestad, Beresford	2/26/98	2.50d	3/2/98
10.15 Approve Project Plan	Sramek, Brundage	3/2/98	5.00d	3/9/98
100 Deign	**Beresford**	**8/28/97**	**80.25d**	**12/23/97**
100.05 System Design		8/28/97	65.25d	12/2/97
100.10 Survey Marktplace		12/2/97	5.00d	12/9/97
100.15 Block Diagram		12/9/97	5.00d	12/16/97
100.20 Techinical Notes		12/16/97	5.00d	12/23/97
200 Documentation		**12/23/97**	**369.75d**	**6/9/99**
200.05 System		12/23/97	369.75d	6/9/99
200.10 Fiber Optics		12/23/97	369.75d	6/9/99
200.15 RF Conversion		12/23/97	369.75d	6/9/99
200.20 Data Communications		12/23/97	369.75d	6/9/99
200.25 Timing/Synchronization		12/23/97	369.75d	6/9/99
200.30 Parts Lists/Data Sheets		12/23/97	369.75d	6/9/99
200.35 Schematics		12/23/97	369.75d	6/9/99
210 Reviews		**12/23/97**	**348.00d**	**5/10/99**
210.10 Hardware		12/23/97	348.00d	5/10/99
210.20 Software		12/23/97	106.75d	5/28/98
250 Fiber Optics Laboratory	**Beno**	**3/9/98**	**20.00d**	**4/6/98**
250.05 Designate AOC Lab Area		3/9/98	20.00d	4/6/98
275 Procure	**Beresford**	**1/2/98**	**133.00d**	**7/10/98**
275.05 Technican		2/26/98	95.00d	7/10/98
275.10 Lab Components		1/2/98	40.00d	2/27/98
275.15 100K Spool		1/2/98	40.00d	2/27/98
275.20 Tooling		1/2/98	40.00d	2/27/98
275.25 Splicer		1/2/98	40.00d	2/27/98
275.30 Loss Set		1/2/98	40.00d	2/27/98
275.35 OTDR		1/2/98	40.00d	2/27/98
275.40 Spec Analyzer		1/2/98	40.00d	2/27/98
275.45 Laptop Computer	Koeld	2/11/98	75.00d	5/28/98
275.50 Test Equipment Received		3/2/98	1.00d	3/2/98
300 Fiber Cable WNMT Co	**Beresford**	**2/2/98**	**36.00d**	**3/24/98**
300.05 Purchase Termination Hdw		2/2/98	25.00d	3/9/98
300.10 Terminate Dark Fiber		3/10/98	10.00d	3/23/98
300.15 Splice Intermediate Locations		3/10/98	10.00d	3/23/98
300.20 Charactize Fiber		3/10/98	10.00d	3/23/98
300.25 Fiber Cable Tested		3/24/98	1.00d	3/24/98
400 Fiber Optics Analog	**Beresford**	**12/23/97**	**334.75d**	**4/21/99**
400.05 Detail Schematic		12/23/97	90.00d	5/1/98
400.10 Purchase Rx module		2/2/98	25.00d	3/9/98
400.15 Construct Prototype Tx unit		2/2/98	84.00d	6/1/98
400.16 Test Prototype Tx/Rx Module		6/2/98	43.50d	8/3/98
400.18 Milestone Rdy 1 IF Fringes		8/4/98	0d	8/4/98



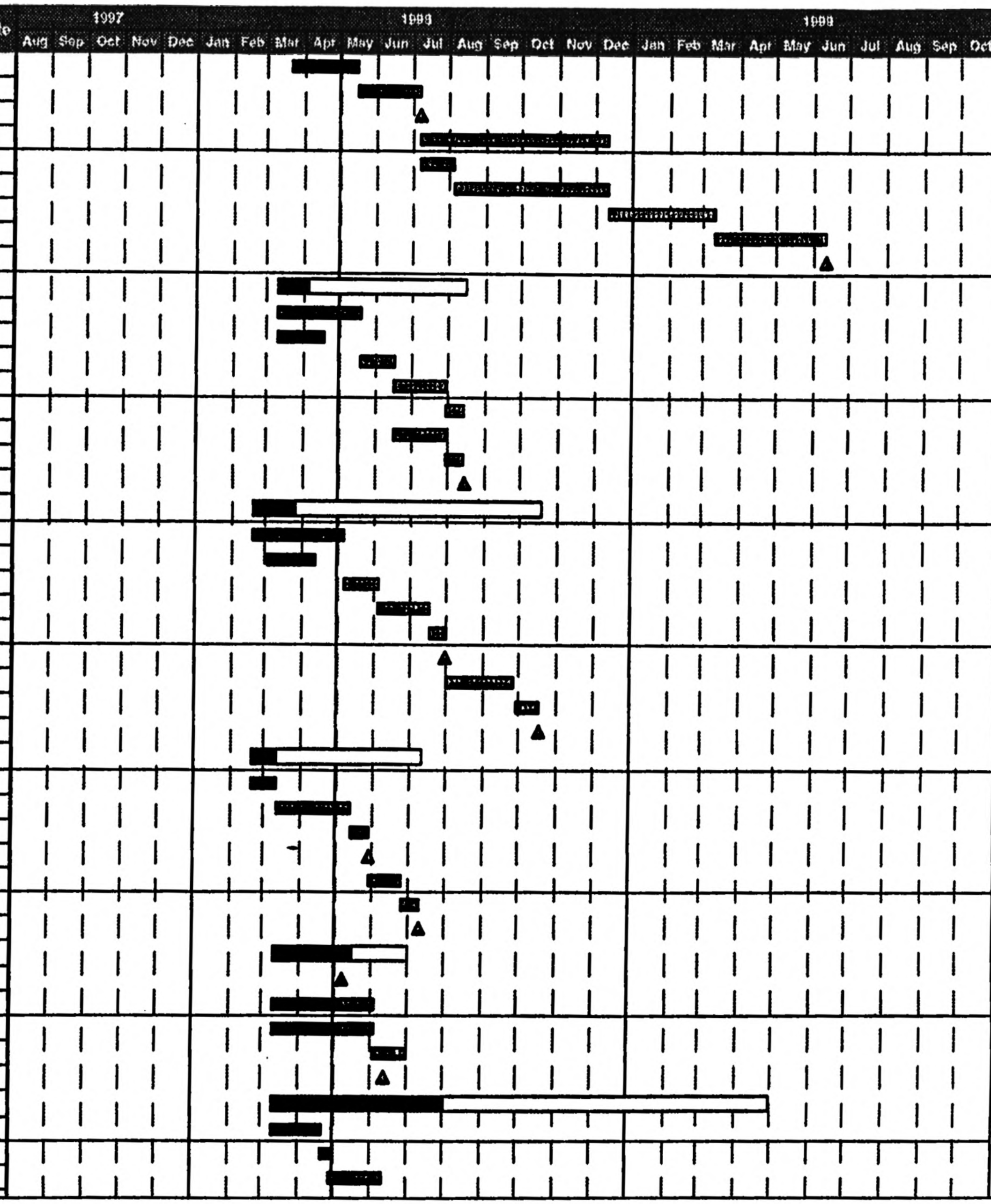
VLA-PTLK2

Task Name	Resources	Start Date	Duration	End Date
400.20 Purchase WL Mux PT		11/2/98	30.00d	12/15/98
400.25 Purchase WL Mux VLA		11/2/98	30.00d	12/15/98
400.30 Construct Mux Modules		12/16/98	10.00d	12/30/98
400.35 Bench Test Prototype		12/31/98	20.00d	1/28/99
400.40 Construct 2 Tx/Rx Pairs		2/2/99	30.00d	3/16/99
400.45 Assemble FO Modules		3/17/99	10.00d	3/30/99
400.50 Test FO Modules		3/31/99	15.00d	4/20/99
400.51 Milestone Rdy 4 IF Fringes		4/21/99	0d	4/21/99
500 Fiber Optics Digital	**Beresford**	**2/2/98**	**277.00d**	**3/9/99**
500.05 Detail Schematic		2/25/98	120.00d	8/13/98
500.10 Purchase Rx Module		2/2/98	25.00d	3/9/98
500.15 Prototype Tx Module		2/2/98	45.00d	4/6/98
500.20 Bench Test Prototype Tx/Rx		6/17/98	20.00d	7/15/98
500.21 Milestone Rdy 1 IF Fringes		7/16/98	0d	7/16/98
500.25 Integrate G Link Tx/Rx & Test		9/17/98	20.00d	10/15/98
500.30 Assemble FO Module		12/10/98	15.00d	12/31/98
500.35 Construct 2 Tx/Rx Pairs		1/4/99	15.00d	1/22/99
500.40 Assemble FO Modules		1/25/99	15.00d	2/12/99
500.45 Test FO Mmodules		2/16/99	15.00d	3/8/99
500.46 Milestone 4 IF Fringes		3/9/99	0d	3/9/99
600 Monitor & Control Comm	**Weimer, Koski**	**3/9/98**	**135.50d**	**9/18/98**
600.05 Procure G-link Eval Kit (2)		3/9/98	30.00d	4/20/98
600.10 Detail G-link Schematic		4/20/98	45.00d	6/23/98
600.15Fabricate G-link PCB's		6/23/98	30.00d	8/5/98
600.20 Construct G-link Tx/Rx Pairs		8/5/98	30.00d	9/17/98
600.21 Milestone Rdy 1 IF Fringes		9/18/98	0d	9/18/98
625 Control Software		**1/2/98**	**384.00d**	**7/9/99**
625.05 Control Software	Sowinski	4/1/98	115.00d	9/11/98
625.07 Schedule May Software meeting	Ulvestad	5/1/98	5.00d	5/7/98
625.10 Test Software	Sowinski	9/14/98	10.00d	9/25/98
625.15 Procure PCMCIA DIS Card	Digital	1/2/98	25.00d	2/5/98
625.20 Generate Laptop Screens	Koski	4/8/98	90.00d	8/13/98
625.21Milestone Rdy for 1 IF Fringes		9/26/98	0d	9/26/98
625.30 Operational Software	Sowinski	1/4/99	130.50d	7/8/99
62535 Ready for 4-IF Fringe Test		7/9/99	0d	7/9/99
650 Computer Link	**Computer Div**	**2/1/99**	**85.00d**	**6/2/99**
650.15 Computer Proucment		2/1/99	35.00d	3/22/99
650.25 Replace PT Router		3/23/99	35.00d	5/10/99
650.30 Upgrade VLA & PT Router		5/11/99	10.00d	5/24/99
650.45 Verify Network Performance		5/25/99	5.00d	6/1/99
650.46 Milestone Rdy 4 IF Fringes		6/2/99	0d	6/2/99
700 Delays	**Ferraro, Broadwell**	**8/28/97**	**451.00d**	**6/11/99**
700.05 Detail Schematic		8/28/97	45.00d	10/30/97
700.10 Purchase Components		10/31/97	40.00d	12/30/97
700.15 PCB Prototype		12/31/97	35.00d	2/19/98
700.20 Bench Test Prototype		2/20/98	20.00d	3/19/98

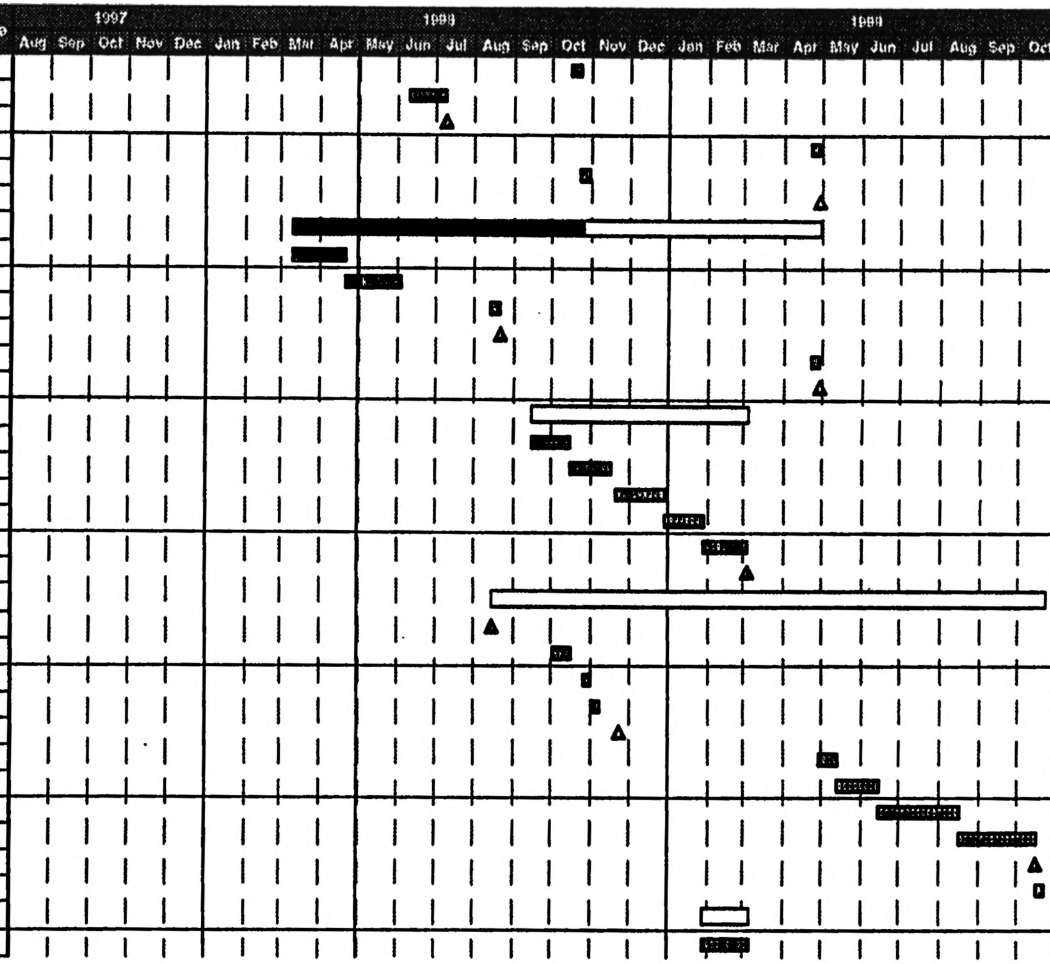


VLA-PTLK2

Task Name	Resources	Start Date	Duration	End Date
700.25 Purchase Components 10 more		3/20/98	40.00d	5/14/98
700.30 Fab 10 more Prototypes		5/15/98	35.00d	7/6/98
700.31 Milestone Rdy 1 IF Fringes		7/7/98	0d	7/7/98
700.35 Modify Delay Cards 250 Cds		7/7/98	110.00d	12/10/98
700.40 System Test Prototype		7/7/98	20.00d	8/3/98
700.45 Prroduction Construction		8/4/98	90.00d	12/10/98
700.50 Production Testing		12/11/98	60.00d	3/9/99
700.55 Installation		3/10/99	65.25d	6/10/99
700.56 Milestone Rdy 4 IF Fringes		6/11/99	0d	6/11/99
800 Switch Module	Cotter, LO/IF	3/9/98	113.00d	8/15/98
800.05 Detailed General Module Sch		3/9/98	50.00d	5/18/98
800.10 Purchase Components		3/9/98	30.00d	4/17/98
800.15 Fabricate PCB		5/18/98	20.00d	6/16/98
800.20 Construct VLA Unit		6/16/98	30 00d	7/29/98
800.25 Test VLA Unnit		7/29/98	10.00d	8/12/98
800.30 Construct PT Unit		6/16/98	30.00d	7/29/98
800.35 Test PT Unit		7/29/98	10.00d	8/12/98
800.36 Milestone Rdy 1 IF & 4IF Fringes		8/15/98	0d	8/15/98
825 Mixer Module	Cotter, LO/IF	2/18/98	170.00d	10/17/98
825.05 Detailed General Module Sch		2/18/98	55.00d	5/5/98
825.10 Purchase Components		3/2/98	30.00d	4/10/98
825.15 Fabricate PCB		5/6/98	20.00d	6/3/98
825.20 Construct Mixer Module 1 IF		6/4/98	30.00d	7/16/98
825.25 Test Mixer Module 1 IF		7/17/98	10.00d	7/30/98
825.26 Milestone Rdy 1 IF Fringes		7/30/98	0d	7/30/98
825.30 Construct 2 2IF Mixer Modules		7/31/98	40.00d	9/25/98
825.35 Test Mixer Modules		9/28/98	15.00d	10/16/98
825.36 Milestone Rdy 4 IF Fringes		10/17/98	0d	10/17/98
850 Reference Splitter Plate	Cotter, LO/IF	2/18/98	100.00d	7/10/98
850.05 General Layout		2/18/98	15.00d	3/10/98
850.10 Purchase Components		3/11/98	45.00d	5/12/98
850.15 Test Splitter Plate		5/13/98	10.00d	5/27/98
50.16 Milestone Rdy I IF Fringes		5/28/98	0d	5/28/98
850.20 Construct 4 IF Mixer Plate		5/28/98	20.00d	6/24/98
850.25 Test 4 IF Splitter Plate		6/25/98	10.00d	7/9/98
850.26 Milestone Rdy 4 IF Fringes		7/10/98	0d	7/10/98
900 Module Modification Work	Cotter, LO/IF	3/9/98	80.00d	6/30/98
900.16 Milestone Rdy 1 IF & 4 IF Fringes		5/7/98	0d	5/7/98
900.25 Modify L1 PT		3/9/98	60.00d	6/2/98
900.30 Modify L2 PT		3/9/98	60.00d	6/2/98
900.35 Test Modified L1 & L2		6/2/98	20.00d	6/30/98
900.36 Milestone Rdy 1 IF & 4 IF Fringes		6/12/98	0d	6/12/98
1000 Rack Hardware VLA	Cotter, LO/IF	3/9/98	288.50d	4/28/99
1000.05 Generate Assy Diagrams		3/9/98	30.00d	4/20/98
1000.10 Assemble Bins A&B		4/20/98	5.00d	4/27/98
1000.15 Wire/Cable Backplanes		4/27/98	30.00d	6/9/98



Task Name	Resources	Start Date	Duration	End Date
1000.20 Install Modules Phase I		10/15/98	5.00d	10/22/98
1000.25 Modify D Rack 1 IF		6/9/98	20.00d	7/8/98
7000.26 Milestone Rdy 1 IF Fringes		7/9/98	0d	7/9/98
1000.30 Install Modules Phase II		4/21/99	5.00d	4/27/99
1000.35 Modify D Rack 4 IF		10/22/98	5.00d	10/29/98
1000.36 Milestone Rdy 4 IF Fringes		4/28/99	0d	4/28/99
1100 Rack Hardware PT	**Oty, VLBA Field GP**	**3/9/98**	**288.50d**	**4/28/99**
1100.05 Generate Assy Diagrams		3/9/98	30.00d	4/20/98
1100.10 Wire/Cable Backplanes		4/20/98	30.00d	6/2/98
1100.20 Install Modules Phase I		8/12/98	5.00d	8/19/98
1100.21 Milestone Rdy 1 IF Fringes		8/21/98	0d	8/21/98
1100.25 Install Modules Phase II		4/21/99	5.00d	4/27/99
110026 Milestone Rdy 4 IF Fringes		4/28/99	0d	4/28/99
1150 Delay of Data Invalid	**Ulvestad**	**9/15/98**	**116.00d**	**3/3/99**
1150.05 Testing with VLA		9/15/98	21.75d	10/14/98
1150.10 Software or Hardware Mods		10/15/98	21.75d	11/16/98
1150.15 Testing with IF System		11/20/98	25.00d	12/28/98
1150.20 Final Design		12/29/98	21.75d	1/28/99
1150.25 Ready for 4-IF System		1/28/99	21.75d	3/2/99
1150.30 Data Invadid Milestone 4-IF		3/3/99	0d	3/3/99
1200 System Integration	**Beresford**	**8/15/98**	**300.63d**	**10/22/99**
1200.02 Request VLA/PT Test Time	Ulvestad	8/15/98	0d	8/15/98
1200.05 Bh Test protot LO,Conv,FO 1 IF	Cotter, LO/IF	10/1/98	10.88d	10/15/98
1200.10 Install Prototype at VLA & PT	Oty, Cotter	10/26/98	5.00d	10/30/98
1200.15 First Fringes 1 IF		11/2/98	5.00d	11/6/98
1200.16 Milestone Obtained Fringes 1 IF		11/23/98	0d	11/23/98
1200.20 Install VLA& PT equip at VLA	VLBA Field GP, LO/IF	4/28/99	10.88d	5/12/99
1200.25 Install PT equip at PT	VLBA Field GP	5/12/99	21.75d	6/14/99
1200.30 Conduct System Test		6/14/99	43.50d	8/16/99
1200.35 First Fringes all IF's		8/16/99	43.50d	10/15/99
1200.36 Milestone Obtained Fringes 4 IF		10/16/99	0d	10/16/99
1200.40 Project Complete		10/15/99	5.00d	10/22/99
1500 Spare Modules		**1/28/99**	**25.00d**	**3/4/99**
1500.05 Decide Spare Module Design		1/28/99	25.00d	3/4/99

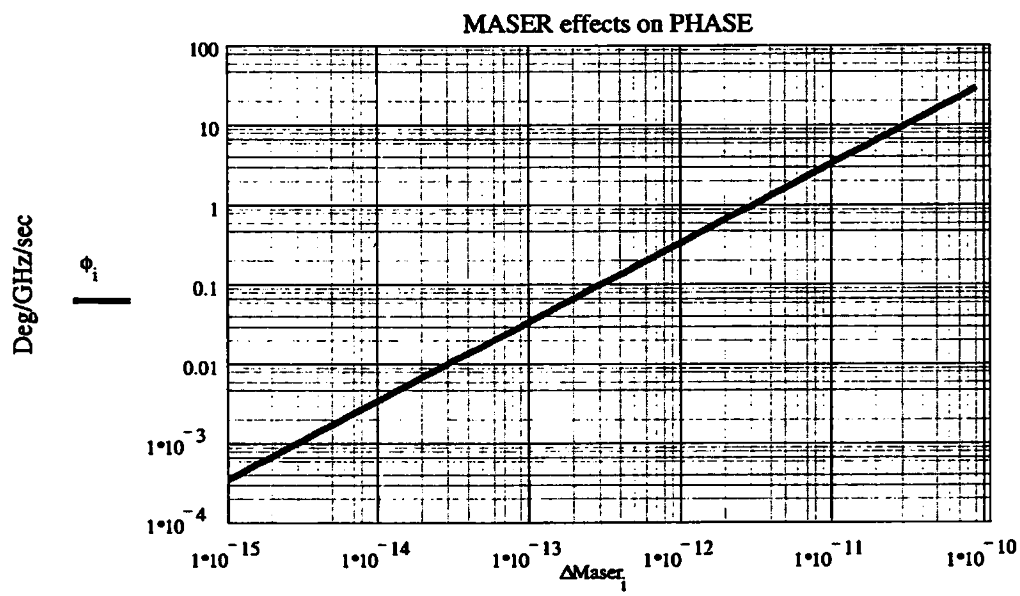


Engineering Report - Pietown to VLA Project

Ron Beresford 29 Jan 99

This report is intended as a brief discussion on the results of the Nov/Dec "first fringe" tests that are going to impact further engineering and construction effort.
Although first fringe tests were highly successful a number of aspects concerning the initial design B12625B001 Rev 2 need to be addressed before "real" observing can be performed.

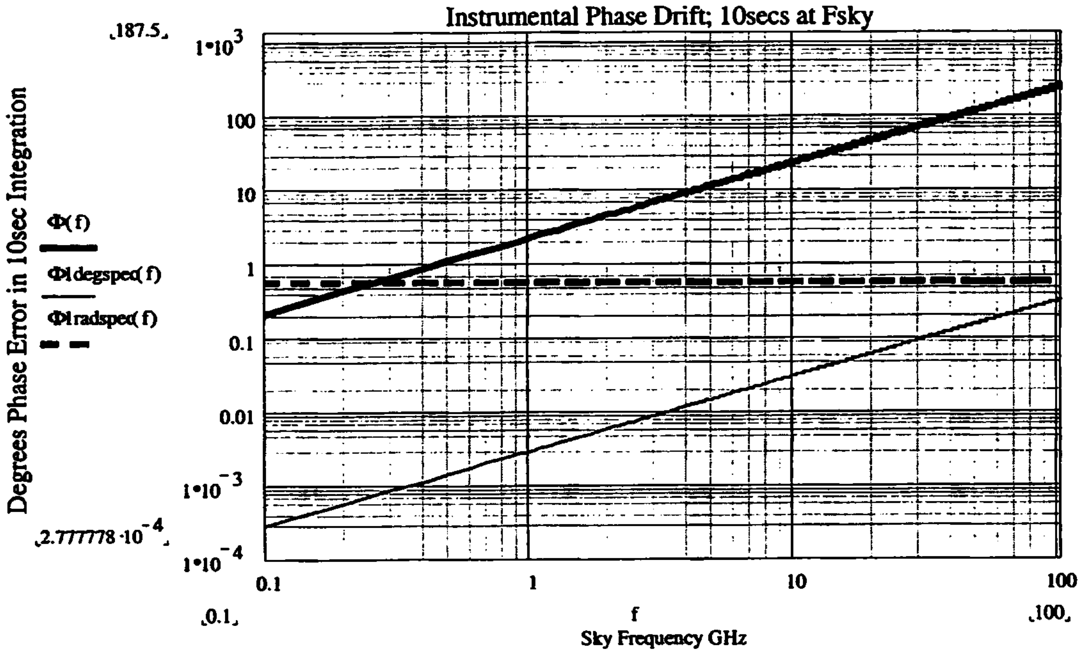
1. The VLA EFOS Maser is a fairly poor time standard for the integration intervals required of the system (seconds to minutes) causing major drifts in visibility phase (approximately 10deg @4.8GHz in 10sec integration periods).
As per the Rev2 block diagram a 1200MHz carrier intensity modulates the PT optical carrier. This is derived directly (via L1, L2, and L3) from the PT 5MHz maser standard.
It can be seen from the L11 one way phase plots that for the few hours of operation during tests on Dec 8^{th} the difference between the 1200HMz at PT and the 1200MHz from the Master LO at the VLA is five complete turns (1800 deg of phase in 2.4hrs or 0.2deg/sec) or 5 parts in 10^{13}.
The Masers at both sites are continually checked and logged via the GPS 1pps standard.
From this data the Sigma Tau stays within 0.1 µS over many days of time. The EFOS is prone to wander 1.2 µS in as little as 48hrs.



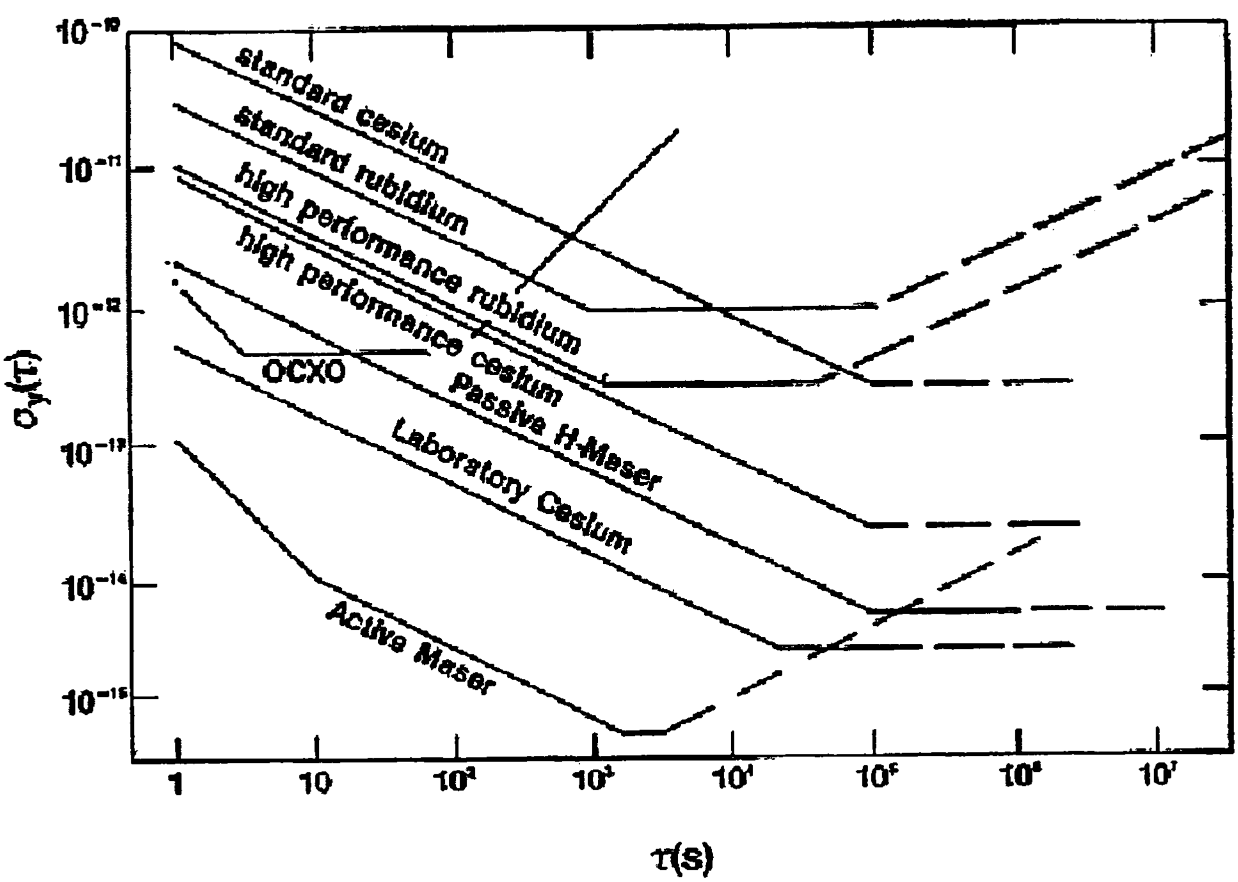
The above shows the number of degrees per GHz per second of instrumental phase error due to the Maser frequency differential. Actual visibility phases would be even worse than this when all the hardware and electronics between the aperture of the antenna and the correlator is considered.

The graph below shows the same as accumulated phase error in a 10 second integration period.

$\phi(f)$ is the phase as realized by the existing system.
ϕ1degspec(f) is the phase specification based on a 1deg/GHz/hr drift.
ϕ1radspec(f) is the phase specification based on a 1 radian drift at any observing frequency in the time between calibrators (say 20minutes).

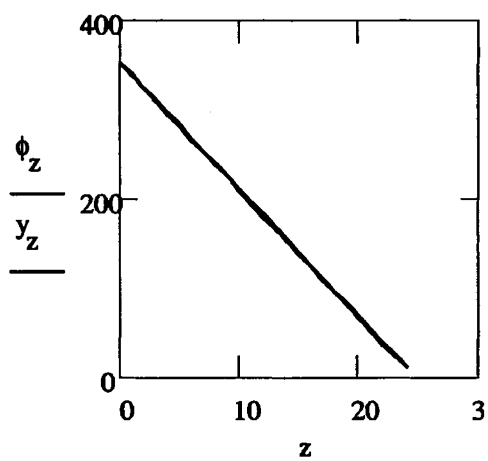


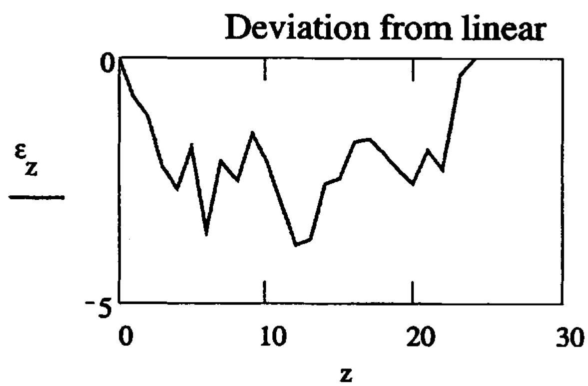
Another interpretation of the "tough" 1deg/GHz/hr specification is that the Masers used should be matched to about 2 parts in 10^{15}. Even the best active masers will have difficulty meeting this. As shown in the plot below of fraction frequency stability for several precision standards. A more realistic approach (assuming the Maser differential drift rates are stable over short time Intervals) is to measure the phase drift and apply a correction to either the visibility phase or servo a anti- phase into the PT phase rotator.

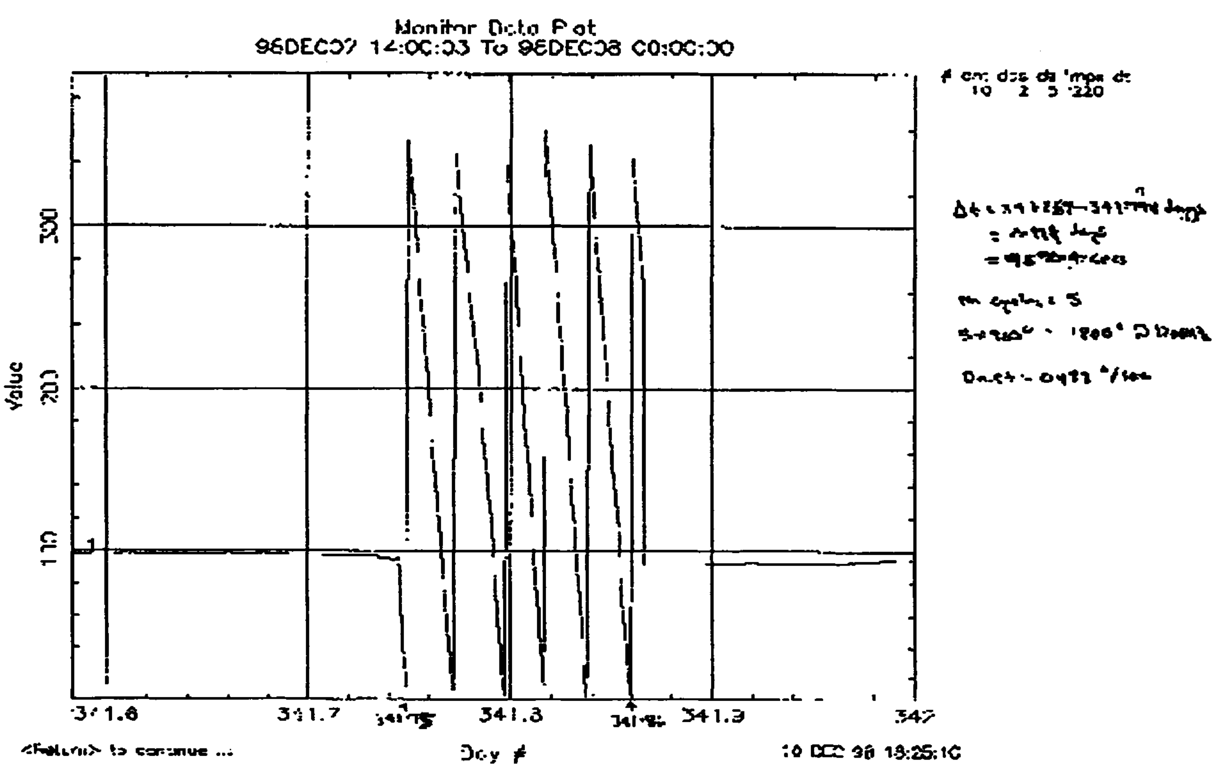


Another necessary measurement is that of the transmission line itself, since the change in electrical length with temperature (perhaps as much as 50mm in a diurnal cycle) will effect the 1200HMz Maser phase calculation and hence F_{sky} calculation. In addition the electrical line length will affect the IF transmission phase at 1325,1425,1575,1675 MHz. Thus the electrical line length change affects the visibility phase in two distinct ways.

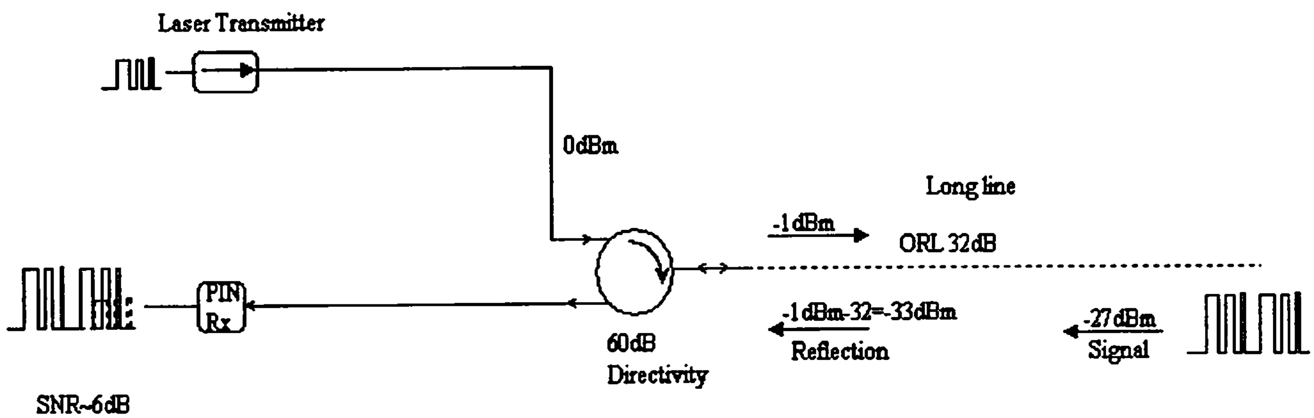
Over the years many methods have been suggested to measure transmission line length with the accuracy required to perform high frequency receiving , ALL require sending a signal of suitable wavelength to provide the sensitivity to changes into the transmission line and then reflecting the same or similar signal from the far end of the transmission line and hence compare the out going with the returned.
Below is a crude sample of deviation from the linear of the 1200MHz carrier from PT for a set of 25 points at 80sec intervals. Also shown is the L11 monitor point data for the 1200MHz one way phase.



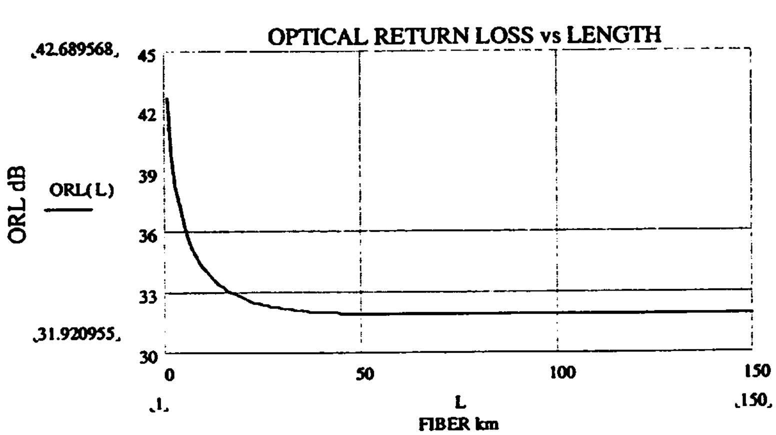


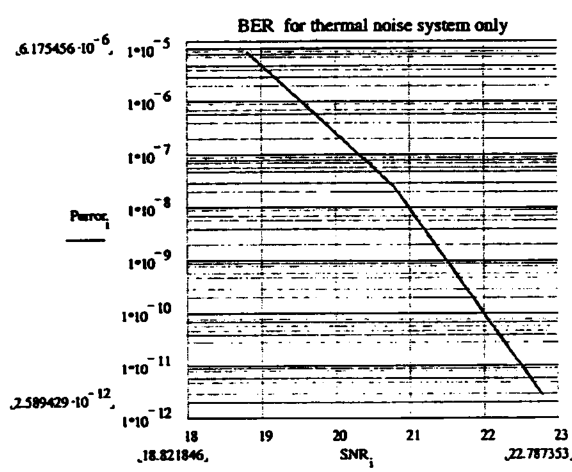


2. The digital transmission link established by the M32 Digital Transceiver modules intended for each site worked with a small optical power margin (2dB) at 600Mbit/sec on the bench over a 104km test spool. The same hardware out at the VLA was generating intermittent L8 sync errors as fiber optic connectors were reconfigured during the early test sequences. The link bit rate was reduced to 200Mbit/sec; the optical power margin was now a healthy 6dB. But still there were problems. When the link was established between PT and the VLA command strings were being lost to the L7 phase rotator every 5 minutes or so. Again it was suspected that reflections from dirty and now well used connectors were at fault. [redacted]



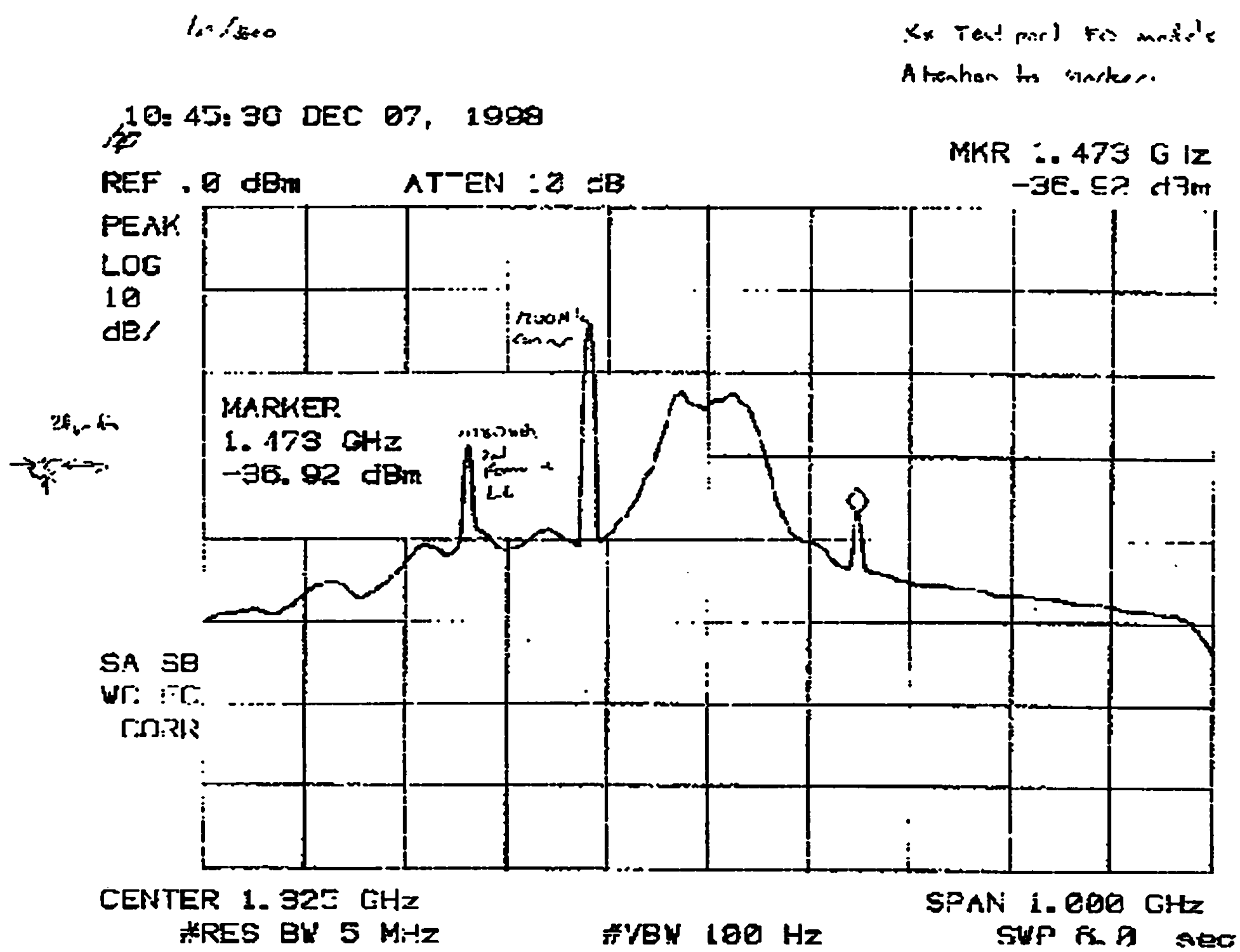
Circulator or Directional Coupler





For thermally noise limited digital transmission standard error functions provide a good estimate of the BER . As depicted above a SNR of better than 22dB is required for BER 1×10^{-10}. For a high performance data link BERs are typically 1×10^{-9} to 1×10^{-13} or better.

3. The "70MHz" bandpass filter used in the Pietown T201A IF converter module was originally a RLC 76MHz 3 pole filter centered at 1325MHz (BPF –500-1325-76-3-RF) .This was later changed to a K&L 50MHz 8 section filter centered at 1325HMz (8B120-1325/50-O/OP).
The steeper skirts provided better rejection of the 2[rd] harmonic of the L6 539.9MHz mixer LO,a common LO for USB conversion at A channel . This 2[nd] Harmonic at 1080HMz mixes with the 1200MHz LO in the T3 image reject mixer module to generate a LSB product at 120MHz .The 120MHz then beats with the IRM LO at 100MHz ,(setting at 50MHz BW) to put a substantial spike in the autocorrelation spectrum only of PT, at 20MHz.
Further perusal of the VLA F7 and F8 modules revealed that Interdigital filters are actually used. Eg. RLC F-3685A 60MHz bandpass.
The group delay and bandpass amplitude characteristics will now being examined in the laboratory with the HP8510 VNA to provide a bandpass filter that meets the PT link requirements and the VLA crosscorrelation requirements. Hopefully the strange 2-3dB " saddle" in visibility amplitudes involving PT will be explained if not removed.
The following plot was obtained from the fiber optic analog receiver module front panel test port.



It sounds like almost certainly we will need two fibers.

SYSTEM DESIGN MODIFICATION PROPOSALS

rjb 29Jan99

At present there are 5 practical ways that the existing V2.0 system design could be altered to implement a working 4 IF ,round trip Φ measurement system ,utilizing a SINGLE fiber core.

1. Phase lock a 5MHz VCXO at Pietown to the VLA Maser. This would entail disconnecting the PT maser from the PT LO conversion chain for the duration of the extended A configuration observing. (Oct.29, 2000 – Jan. 8, 2001).
A relatively low power DFB laser (+10dbm)at λ2 could be externally modulated at the VLA with the standard MLO 1200&1800MHz carriers. The addition of a L4 Antenna RX module and a L5 LO control/loop filter module at the PT end will lock the L1 at Pietown to the VLA. In the VLA the L1 normally free wheels for 51ms in the VLA TDM waveguide cycle , in this design the L1 VCXO will be continually locked.
The changes in 104km of transmission line can be calculated by comparing the phase of the 1200MHz carrier (sent with the IF A,B,C,D at λ1) returned to the VLA with the MLO 1200MHz as per existing setup.
Bidirectional data transmission can continue with the current scheme using λ3,λ4 optical channels.

Problems: 1. Excessive phase noise PT LO's.
2. Do we really want PT run by EFO's maser?

Buy: . Laser . Ext. modul. . FLT?
Need: . more rack space @ PT

(seems to automatically fix the 18 problem)

2. As per proposal 1 ,the bidirectional analog connection is retained at λ1,λ2. The bidirectional data would be amplitude modulated onto the 1800MHz carriers in both directions in the same way as the VLA currently operates. The addition of an L9 Central LO Rx and L10 Central LO Tx at the VLA would be required , if monitoring of the VLA "donor" antenna is to continue. The data Tx from PT can use the existing L3 module in the PT reference chain.
The synchronizing of PT to VLA waveguide cycle will come for "free" by virtue of the 5MHz modulation being turned on and off the 1200MHz carrier in the new L4,L10 combination.
The great advantage of this layout is that the system (at the expense of adding several new modules) now only requires 2 optical wavelengths λ1,λ2.

Assumes dispersion of fiber not a probl. (?)
Concerned about complicating DWDM in #1 above?

3. Continue with the current V2.0 design but reflect a received 1800MHz carrier from the VLA ,back to the VLA. The addition of an L14 Central LO filter module (NB PLL) will be required at the VLA. The 600MHz ZXD output can be fed into the spare (5MHz ambiguity port) of the current donor D rack L11.
There is enough signal to noise in the system without a narrow-band PLL at PT to recover the 1800MHz from the VLA and retransmit it alongside the PT IF's A,B,C,D and 1200MHz ,and still measure the electrical length to about 1 degree in phase at 1800MHz. The Δ at 1800MHz will apply to IF phase correction and when subtracted from the Δ at 1200MHz will provide the Maser differential phase as applied to the PT LO chain and required anti-setting in the PT phase rotators.

4. Continue with the V2.0 design but align Masers to provide a differential drift rate in which the Δ phase is monotonic with time. Again the Φ offset required as a anti-setting in the L7 phase rotators at PT can be calculated. The problem with this approach is the uncertain erratic behavior of the VLA EFOS Maser .
If the EFOS were replaced with a new maser , that could be aligned to better than 2 in 10^{15} then the LO chains at both sites could be considered coherent enough to meet the 1deg/GHz/hr specification without measuring the Φ. The transmission line effects ,most likely can be measured directly by a one way Φ measurement of the 1200MHz carrier from PT to the VLA only.

X7299

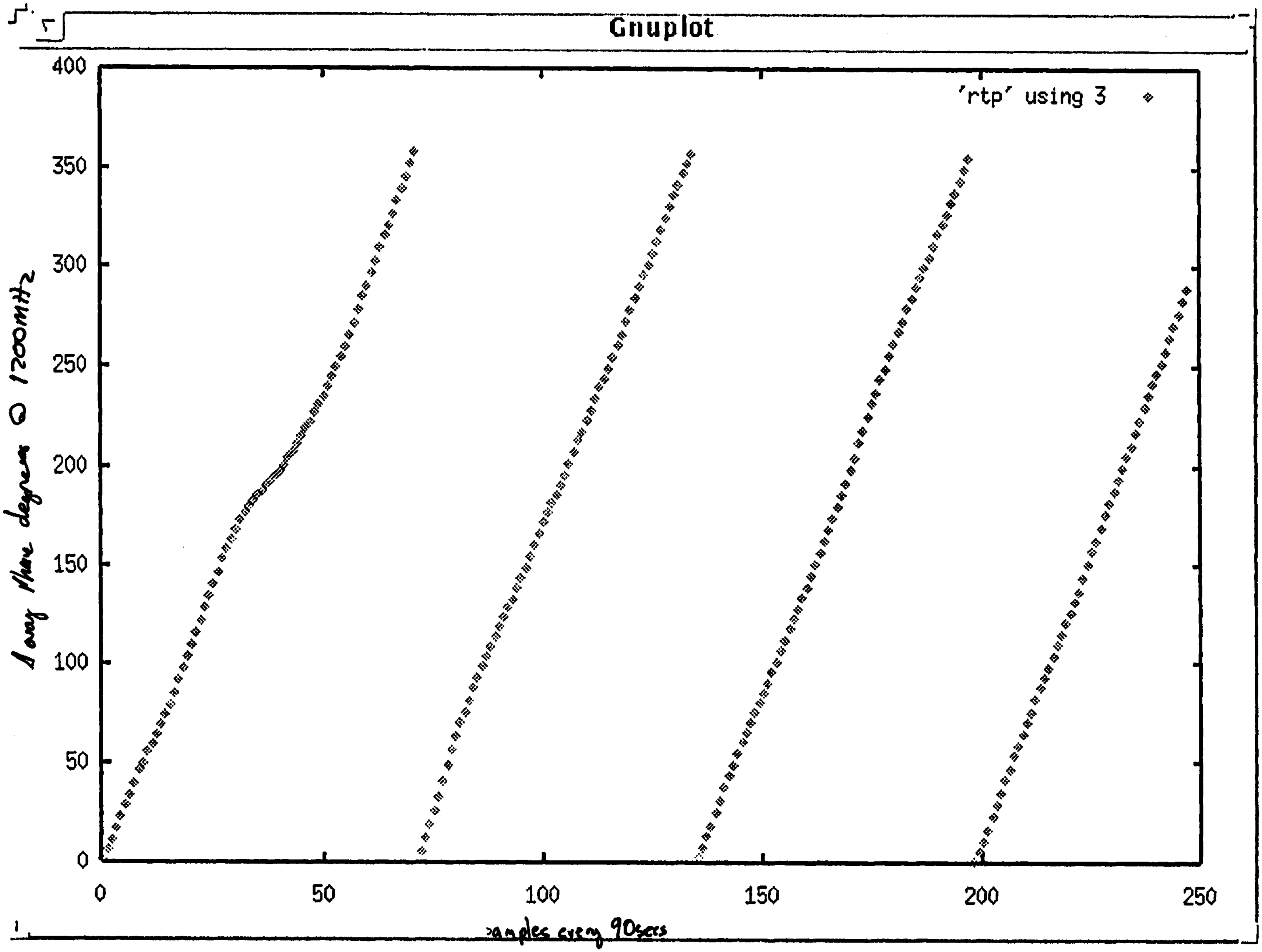
5. With the current V2.0 layout switch the 1200MHz signal at PT from the PT reference derived 1200MHz to a VLA Fiber optic distributed 1200MHz at λ2 from the VLA Master LO. This could be done every alternate waveguide cycle. The addition of an active switch at the PT end will suffice the switching , in synchronism with the bucketing of L11 results into two bins 1200MHz (Maser) and 1200Mhz (Transmission line) . This may be a tricky implementation to code.
This system still requires 4 optical channels λ1,λ2,λ3,λ4.

Summary. Option 3 holds the best promise for making a system that meets the phase stability specifications while minimizing the amount of additional hardware . Unfortunately it is adding further complexity to the optical filtering and MUX/DEMUX requirements. A bi-directional optical system with 4 optical channels λ1,λ2,λ3,λ4 , where λ1,λ3 are in one direction and λ2,λ4 in the opposite direction and where λ1,λ2 are high SNR analog channels and λ3,λ4 digital channels ,all requiring approximately 50dB of adjacent channel rejection will be a challenging construction.

This challenging DWDM approach is made even more so by the limited availability of 1550nm laser devices that are wavelength selected and also meet the power requirements needed for the high optical loss of 104km of fiber plus notable losses of passive optical MUX/DEMUX devices.

The DWDM approach in option 3 is in the spirit of using the most up to date techniques with a view to applications in other phased array developments.

Any shortfalls in the implementation for the June99 VLA "A" configuration can be overcome by resorting to a 2 fiber system greatly easing the optical requirements.


Gnuplot
'rtp' using 3
400
350
300
250
200
150
100
50
0
0
50
100
150
200
250
samples every 90secs

Subject: thoughts on SW issues for the Fall test
Date: Mon, 6 Apr 1998 10:03:06 -0600 (MDT)
From: Ken Sowinski <ksowinsk@arana.aoc.NRAO.EDU>
To: julvestad@arana.aoc.NRAO.EDU, rberesford@arana.aoc.NRAO.EDU, dsramek@arana.aoc.NRAO.EDU, wkoski@arana.aoc.NRAO.EDU, cbroadwell@arana.aoc.NRAO.EDU
CC: bsahr@arana.aoc.NRAO.EDU

The following message is a list of the things I have thought of so far. I welcome any comments, corrections or notices of omission.

This is a list of what software and information is needed to be able to conduct simple tests using Pietown this fall. I will try to keep this list up to date as we think of new things as well as when tasks are completed. I assume that what we want is only enough support to make simple tests.

At Pietown. For this purpose all we need is a VLBA observe file which looks at our favorite calibrator at some interesting frequency. If any LOs at PT are to be controlled by the PT computer it is sufficient to be able to set them manually.

At the VLA. This will be a longer list. To calculate phases and delays we need to know:

1) the position of PT in the VLA coordinate system. I have calculated this given that PT is at 34 18 03.61, 108 07 07.24 and 2371m but these coordinates are only accurate to a foot or so. Does anyone care to verify this or do better?

2) the k-term for PT I have been told is about 2m. We don't need this to be right to make fringes but it would be nice to have it close. Is 6ns good enough?

The first step is to get the antenna coordinates into the system. Changes are required to the function that reads the BASELINE file and to the program that estimates the antenna "cable" delay. These changes have been made and will be in the mid-April update. After that I will extend the BASELINE file to include PT.

Next we will have to decide how to deal with communicating to the correlator the expanded delay space that is required. Chuck tells me that he expects to be able to work on the changes needed to the system controller to be able to accept larger delay values and send them on to the physical delay lines. If he gets this done in time only two changes are needed to accomodate PT. The first is to change a constant to shift the range of delay space that is occupied by the delay values sent to the correlator. This change is valid only for PT-related observations when all the relevant antennas have expanded delay lines. The second is to modify the task in spectre that sends delays to the correlator. This change, as well as Chuck's to the system controller may be left in place, once tested, with no adverse effect on ordinary observing. If Chuck is not able to have the system controller ready in time there are other, kludgy, ways to deal with the expanded delay space. I would strongly prefer not to have to do this.

With these changes in place if an antenna is marked in the ANTENNAS file as being on the "pad" called PT, then I claim that I will properly calculate everything necessary to correctly run the delay lines and the lobe rotaters. This will be verified in May or June.

It will also be necessary to examine the LO chain with care to be sure that the relationship between the 10.1MHz which has the fringe frequency imposed on it and the signal to be mixed is the same as in the existing antennas. If there are and LOs to be controlled by the Modcomp and unique to the PT antenna it will proably be necessary to set them manually.

If phase switching is not put in place or not synchronized properly at PT we can do the experiments with phase switching disabled for the PT antenna.

If we have no reliable sync detector measurement, tests should be made with the system temperature correction disabled.

I suggest that we ignore the data-invalid overrun for these tests. Either we do nothing or construct a little box that will generate a suitable gating signal so that the correlator is blanked during the time that valid data is known not to be present. If we decide to slide data invalid, the necessary changes in the system controller *may* be complicated enough that we could not get it done in time. We should decide soon whether this is important.

I envision the following sequence to replace a VLA antenna with PT.

1) Secure the VLA antenna that we wish to set idle for the test.
2) Modify the ANTENNAS file so that that antenna is on the PT "pad" and has a K-term of about 6ns.
3) Make all necessary cabling changes so that PT IFs wind up in the purloined D-rack and so that monitor and command data flow to the right places. For this test I expect that all equipment related to PT will use the DCS number of the purloined antenna. Is that a problem?
4) Invoke an appropriate observe file at PT and at the VLA.
5) Invoke a modified version of the VLA source change program that understands what delay range must be used.
6) Watch the fringes on D10.

With regard to online software I see only two important things that must be settled before the Fall test:

1) Do we want to shift data invalid as seen by the correlator?
2) Is it acceptable to control all PT-related equipment using the DCS number of the idled antenna?

May 13, 1998

Software requirements for first VLA-PT fringes, as seen by JSU

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(1) Supply a CRD file for PT that observes the correct source at the right time and frequency band, and puts the proper IF frequency into the spigot heading for the conversion modules for the fiber.

(2) Provide the proper commands to the conversion modules at PT to make the VLBA IF into an apparent VLA IF. Provide a means for adjusting things in real time, if necessary.

(3) Control the fiber link by whatever means necessary.

(4) Provide someone at the VLA with the capability of monitoring the link and (possibly) of checking the performance of the VLBA front end.

(5) Get the PT IF signal sent to the appropriate D-rack in the VLA electronics room, and properly identify the antenna using that D-rack. Command PT equipment using the appropriate DCS number.

(6) Set the delays in the correlator as necessary for the test with four VLA antennas plus PT.

(7) Get PT fed into a standard display so that it's possible to see whether there really are fringes.

(8) Items that must be dealt with eventually, but are probably not required for first fringes, include phase-switching, Tsys measurement, and fixing the over-run of the data-invalid period.

there is no need for 9.6Hz Noise cal for initial tests
Ken suggest controlling the NCAL from VLBA equipment.

PT IF is initially single frequency and single polarization

Subject: VLA-PT Link Software Meeting, 13 May 1998
Date: Fri, 15 May 1998 12:37:05 -0600 (MDT)
From: Jim Ulvestad <julvesta@arana.aoc.NRAO.EDU>
To: dbagri@arana.aoc.NRAO.EDU (Durgadas Bagri), rberesfo@arana.aoc.NRAO.EDU (Ron Beresford), sblachma@arana.aoc.NRAO.EDU (Steve Blachman), cbroadwe@arana.aoc.NRAO.EDU (Chuck Broadwell), bbrundag@arana.aoc.NRAO.EDU, jcampbel@arana.aoc.NRAO.EDU (Jack Campbell), bclark@arana.aoc.NRAO.EDU (Barry Clark), rferraro@arana.aoc.NRAO.EDU (Ray Ferraro), wkoski@arana.aoc.NRAO.EDU (Wayne Koski), rlong@arana.aoc.NRAO.EDU (Robert Long), rperley@arana.aoc.NRAO.EDU (Rick Perley), ksowinski@arana.aoc.NRAO.EDU, dsramek@arana.aoc.NRAO.EDU (Dick Sramek), cwalker@arana.aoc.NRAO.EDU (Craig Walker), jwrobel@arana.aoc.NRAO.EDU (Joan Wrobel)

15 May 1998

TO: Distribution

FROM: Jim Ulvestad

SUBJECT: Minutes of VLA-PT Link Software Meeting, 13 May 1998

ABSTRACT

On 13 May, a meeting was held to discuss the software requirements for the first 1-IF fringe tests for the VLA-PT link, currently scheduled for late 1998. Since a number of decisions for the software for the operational 4-IF system will be delayed until after the experience gained in these tests, the software modifications at this stage will emphasize the minimal changes needed to make the link work in a "hands-on" mode.

ATTENDEES

Beresford, Blachman, Campbell, Clark, Sowinski, Ulvestad, Walker

AGENDA

There was no formal agenda. Instead, the meeting worked through two overlapping lists of items that need to be addressed. One list was generated in an e-mail from Ken Sowinski in early April, while the supplementary list was prepared by Jim Ulvestad on the day of the meeting.

SUMMARY
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(1) The (summed) first LO from the VLBA needs to be communicated to Ken Sowinski, so that he can compute the proper frequencies for the conversion equipment that will make the VLBA IF signal "look like" a VLA IF. The value of this LO will be built into the VLA OBSERV file.

(2) In order to properly operate the modified L7s at PT, it is necessary to know the sideband where the fringe rotation is applied, relative to the sideband where it is applied at the VLA antennas. This will be different for different observing bands, since PT will nominally use upper sideband, while the different VLA bands may be either upper (e.g., 5 GHz) or lower (e.g., 8 GHz) sideband.

(3) The modified L6 has a switch for HI/LO output, related to the sideband conversion, that will be controlled in software from the VLA Modcomps. The exact mechanism for this will be sorted out in the next 2 months.

(4) Nothing special needs to be done to turn the fiber link on and off at this stage.

(5) VLBA monitor screens will be provided at the VLA, as they are now available for the VLA when it participates in VLBI observations. This is not a problem.

(6) It has been decided not to invent a new DCS number, DCS 34, at this stage, because implementation of that number will take more work now than later. Instead, PT will be assigned the DCS number corresponding to the D-rack that is being borrowed from a VLA antenna. This will require moving some cables around. Using an existing DCS number means that the existing VLA displays (e.g., D10 fringe display) will handle the PT antenna with no additional modifications needed.

(7) An equivalent to the round-trip phase information will be sent over the fiber line to the L14 module at the VLA. The round-trip phase correction can be enabled or disabled on an antenna-by-antenna basis in the VLA software, and this will be done as the need arises.

(8) The new code to handle the larger delays that are used in the VLA correlator will be in place by late August. Since only a few delay boards will be modified by that time, this may necessitate some switching back and forth, which will probably cause there to be two possible values for the phased-VLA delay for VLBI observations. This is an operational issue that needs to be carefully monitored.

(9) Geodetic PT coordinates must be properly rotated and specified in the VLA coordinate system.

(10) The k-term (axis offset of the phase center must be properly applied at PT, and no one knows the sign of that term relative to the VLA antennas from first principles. The delay offset will be about 6 nsec, which should not be a significant issue. The sign will eventually be figured out from experience.

(11) The L8 will be in place to enable PT phase-switching, although that does not seem to be necessary for first fringes. The phase switching will be used or turned off, as necessary.

(12) There was some discussion of using the pulsar gate to gate the correlator, if necessary, to fix up the non-overlapping data-invalid intervals. However, this is not thought to be necessary for first fringes, where we can tolerate the (roughly) 0.5 milliseconds of invalid data that get to the correlator outside the correlator's data-invalid period.

(13) Throughout the meeting, there were tangential discussions on the plans for the 1-IF tests. Rather than report the various ideas now, it was agreed that Jim Ulvestad would start preparing a draft test plan over the next month or two.

Distribution: Bagri, Beresford, Blachman, C. Broadwell, Brundage, Campbell, Clark, Ferraro, Koski, Long, R. Perley, Sowinski, Sramek, Walker, Wrobel

Subject: vlba LO settings
Date: Thu, 14 May 1998 10:10:22 -0600 (MDT)
From: Ken Sowinski <ksowinsk@arana.aoc.NRAO.EDU>
To: julvestad@arana.aoc.NRAO.EDU, rberesford@arana.aoc.NRAO.EDU

Someone asked to see the table of LO settings I had compiled.

Here is a table of possible VLBA first LO settings for the standard VLA frequencies. The VLA DC edge frequencies are given. It is possible to tune the two VLA IF pairs in such a way that PT cannot simultaneously tune to them both. The converse is also true. The VLBa LO settings are derived from the tables that Craig has compiled for sched.

Band	AC	BD	VLBA first LO
C	4860.1	4810.1	3.9 or 4.1
U	14.9899	14.9399	14.4
K	22.4601	22.4101	21.5(8.9 & 12.6) or 21.7(9.1 & 12.6) or 21.8(8.9 & 12.9)
L	1.4399	1.3601	2.1(LSB)
X	8.4601	9.5101	7.6 or 9.4(LSB)
Q	43.2899	43.3399	42.4(7.6 & 11.6)

July 11, 1998

TO: Dick Sramek

FROM: Jim Ulvestad

SUJECT: VLA-PT link budget accounting

CC: Ron Beresford, Jack Campbell

Despite repeated requests to the business office, I have not yet received any accounting of the actual dollars spent in the VLA-PT link project, Project Account 12625. I have attempted to reconcile the budget numbers based on the information I have on hand. However, I find myself unable to do so completely, for (at least) the following additional reasons:

(1) There may have been purchase orders that went out early in the lifetime of the project, and for which I did not receive copies.

(2) Since I have no signature authority on the purchase orders, I never get a copy of anything back after orders have been placed. Therefore, I can only rely on the copies I make of the initial purchase orders that go out, with no knowledge of price adjustments, cancellations, or any other information on the status of the requistions.

With the above caveats in mind, and with a summary supplied by Ron Beresford, I have derived the following numbers. There are two budgets for 1998, one from Dick Sramek dated 6 February, and a revision by Jim Ulvestad dated 29 May, based on updated information from Beresford and a subsequent meeting among Sramek, Beresford, and Ulvestad. There are two numbers for the amount spent, one from a summary supplied by Beresford, dated 26 June, and one from the purchase orders initialed by Ulvestad, as of 11 July. As can be seen below, the "as-spent" numbers are not in great agreement with each other, but are actually surprisingly close, given the nature of the input data.

VLA-PT Budget Accounting, Acct 12625 - July 11, 1998 - by Jim Ulvestad

Proj. Code	Budgets ($K) Sramek 6 Feb	Budgets ($K) Ulvestad 29 May	Actuals ($K) Beresford 26 June	Actuals ($K) Ulvestad 11 July
.2030 Test Eq.	89.0	89.0	75.4	60.7
.3030 General	0.0	0.0	15.4	13.4
.3031 Trans/FO	75.0	74.0	28.1	29.7
(.3030 + .3031)			(=43.5)	(=43.1)
.3032 LO/IF	33.0	23.0	1.3	0.5
.3034 M/C	4.0	5.0	3.1	6.9
.3036 Data Comm.	3.0	0.0	0.0	0.0
.3037 Correlator	55.0	55.0	0.3	0.8
.3038 VLA modules	0.0	0.0	0.0	0.0
.3039 Misc.	5.0	5.0	2.1	2.4

Note the following explanations for discrepancies:

(1) It appears that there was at least one major purchase of test equipment for which I did not receive any copies of the purchase order.

(2) The equipment purchased early on in the general code .3030, before it was broken down into the more specific items, was dominated by the purchase of over 100 km of optical fiber, which belongs in code .3031. Therefore, I have added figures (in parentheses) indicating the sum of the purchases under these two numbers.

(3) There are discrepancies of a few hundred dollars accounted for by purchases that have gone out since about mid-June, that are included in my figures but not in Beresford's. Also in this category is a $750 purchase order under account .3037, which was just submitted on July 8.

(4) In account .3034, Beresford's numbers include only the evaluation kits ordered in early April. They do not include the PC order for about $1.7K placed in early February, a recent $1.2K order for PC boards, and a host of small miscellaneous orders adding up to another $0.8K. I suspect that the $1.7K purchase was never made, and may have been superseded, but I have received no information to that effect.

Based on the above accounting, I am initialing and passing on to Sramek purchase orders totaling $8.5K in code .3032, $5.3K (plus one item uncosted) in code .3031, and $0.2K in code .3034. I note that we appear to be overspending the budget in code .3034. However, this depends on whether the February PC order was placed or disappeared. It also appears possible that a lot of miscellaneous components are being ordered under .3034 that may belong in .3039, but I have no insight into whether random resistors, capacitors, and integrated circuits should be identified specifically with monitor and control. If these items really belong under code .3034, we may need to consider increasing that budget item by several thousand dollars.

I'll be out of the country until July 24, but Josette Chavez has my itinerary if there is any need to reach me.

Subject: Re: PT tests
Date: Mon, 2 Nov 1998 15:18:30 -0700 (MST)
From: Ken Sowinski <ksowinsk@arana.aoc.NRAO.EDU>
To: dvanhorn@arana.aoc.NRAO.EDU, phicks@arana.aoc.NRAO.EDU
CC: vlaops@arana.aoc.NRAO.EDU, rberesford@arana.aoc.NRAO.EDU, cbroadwell@arana.aoc.NRAO.EDU

I wrote:

> *Dave,*
>
> *For the PT tests tomorrow, Nov 3, we would like to have the*
> *following antennas operational and available:*
>
> *4, 10, 16, 23 and 25.*
>
> *The fibre will be connected in the signal path for antenna 25*
> *(DCS '10) pad CW1.*
>
> *Please let us know if you need any of these antennas for other work;*
> *if necessary they can be replaced, given sufficient notice.*

Unfortunately I got it wrong. We intend to connect the fibre in the signal path of antenna 10 (DCS '2) pad CW2. Antenna 25 will not be required. We will need one more antenna not on this list for a total of 5 and prefer that it be antenna 22. The complete list of required antennas then is:

4, 10, 16, 22 and 23.

Ron will do his work on antenna 10 and Chuck will have to install modified delay cards for antenna 22.

Sorry for the confusion,
Ken

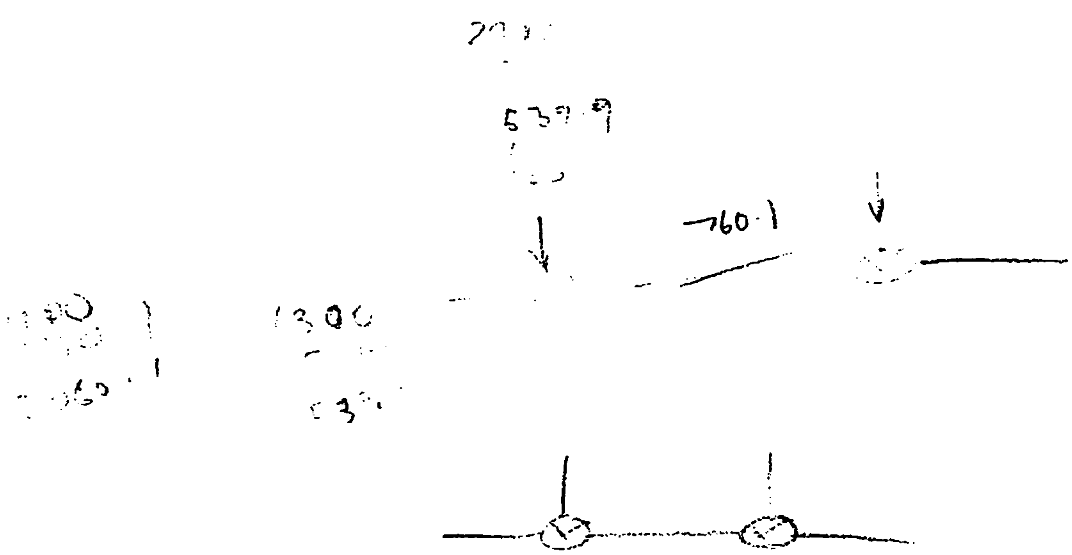
Subject: "plan" for PT tests on Wednesday (and Friday, I suppose)
Date: Mon, 16 Nov 1998 15:38:56 -0700 (MST)
From: Ken Sowinski <ksowinsk@arana.aoc.NRAO.EDU>
To: vlaops@arana.aoc.NRAO.EDU, julvestad@arana.aoc.NRAO.EDU, rberesford@arana.aoc.NRAO.EDU
CC: bsahr@arana.aoc.NRAO.EDU

Protocol for Test 2 -- November 18, 1998
(from the software/operations point of view)

1. Park and secure antenna 10.
2. Select signal donor antenna (preferably 22 or 4 ??).
3. Rewire as necessary.
4. Modify ANTENNAS file to put antenna 10 on pad VPT and swap delay line numbers for antenna 10 and the donor antenna.
5. Modify BASELINE file to put VPT at (0,0,0) so L7 cmds to PT rack are identically zero and adjust delay term for donor antenna if necessary.
6. Set the "IF B" L6 of antenna 10 (PT) to 539.9 by asking for 3540. This will mix the VLA IF to where we would expect it had PT really been used.
7. Use observe file which specifies f(PT) for C band as 4.1GHz.
8. Tune delays for test signal by modifying delay term in BASELINE for the donor antenna.
9. Verify data quality
10. Decide what changes are necessary if we wish to go on to test 4 which does fringe rotation in the PT rack rather than at the VLA donor antenna. Answer: 1) VPT must be placed at the location of the donor antenna and 2) G10 must be run from T32 to guarantee that the fringe rotation commands for the other L7 in the PT rack remain identically zero.

Phase switching should work properly if the delay line numbers are switched as described in item 4.

This test could be done with antenna 10 in one subarray and all the rest in another, but I see nothing to be gained at this stage from such a complication.



Subject: **Re: Pie Town position error**
Date: Thu, 3 Dec 1998 17:18:23 -0700 (MST)
From: Ken Sowinski <ksowinsk@arana.aoc.NRAO.EDU>
To: ksowinsk@cv3.cv.nrao.edu, mclausse@cv3.cv.nrao.edu, julvesta@cv3.cv.nrao.edu, rberesford@arana.aoc.NRAO.EDU

I looked up my notes on the PT position calculation and it looks like Jim's argumnet is plausible.

I initially calculated a rough position using a survey position for pietown. Later Barry used more precise VLBA positions for the VLA and PT. These were differecned and that vector transformed to the VLA coordinate system. The difference in these two positions is about 36ns, more or less 11m., and about the delay differecne we find. Unfortunately I never modified the baseline file to use the refined position!

Further, I calculate that the K term can contribute no more than 10 degrees of phase per 10 seconds of time in the worst case at X band. We know that the cloeck difference can ontribute no more than about 8 degrees of phase per 10 seconds at C band. All these estimates seem to hold together reasnably well.

I will put in the refined PT position. Someone should try to verify that the we think we know the correct sense of the K term at PT. I will see about trying to properly interpret the sense of the RT phase measurement for the PT antenna and will go through the algebra again to see if if can turn RT phase in to visibility phase.

Doing all this should help phase stability a lot. Anyone care to look at and explain bandpasses?

Cheers,
Ken

Subject: First VLA-PT fringes
Date: Fri, 04 Dec 1998 07:23:50 -0700
From: Jim Ulvestad <julvesta@arana.aoc.NRAO.EDU>
Organization: National Radio Astronomy Observatory
To: mgoss@cv3.cv.nrao.edu, pvandenb@cv3.cv.nrao.edu, rbrown@cv3.cv.nrao.edu, rperley@cv3.cv.nrao.edu, abridle@cv3.cv.nrao.edu, dsramek@cv3.cv.nrao.edu, kkellerm@cv3.cv.nrao.edu
CC: ksowinsk@cv3.cv.nrao.edu, rberesfo@cv3.cv.nrao.edu, cbroadwe@cv3.cv.nrao.edu, jwrobel@cv3.cv.nrao.edu, cwalker@cv3.cv.nrao.edu, mclausse@cv3.cv.nrao.edu, pperley@cv3.cv.nrao.edu, julvesta@cv3.cv.nrao.edu, dfinley@cv3.cv.nrao.edu, bclark@cv3.cv.nrao.edu

Hi all,

I thought I should pass on a bit more information on the first VLA-PT fringes. First fringes were acquired on 3C 345 at 6 cm, on Thursday December 3, at about 1730 UTC. Fringes were in Right Circular Polarization, using the modified delay "piggybacks." VLA antennas used were 23 (CW3), 4 (CW4), 17 (CW5), 16 (CW7), and 1 (CW8), with the Pie Town antenna "borrowing" the D-rack belonging to antenna 10, at CW2. Fringes were found within about 5 minutes of the VLA antennas getting on source. The measured delay was about 1.6 microseconds relative to the prediction based on the fiber delay minus the hypothetical waveguide delay to Pie Town. This means that the predicted fiber delay of about 505 microseconds was correct to within about 1.5 microseconds.

There was a considerable phase wind of about 35 to 40 degrees in 10 seconds at IF, compared to an estimate of 5 degrees per 10 seconds from the measured round-trip phase (the latter being consistent with the relative maser drift).

A source change to 3C 454.3 was made to try to investigate the nature of the phase drift. Fringes were found at 6 cm easily. Then, after swapping the IF distributor switch at Pie Town, fringes were found at 1.3 cm and (after correcting an error in the calculated LO) at 3.6 cm. The delay was quite different from 3C 345, by about 20 nsec. Then we went back to 3C 345 and found fringes at 1.3 and 3.6 cm, with the delay 20 nsec different from what it had been 3 hours previously.

Following the tests, we determined that an incorrect Pie Town position was in the VLA antennas file, with an error of about 11 meters, corresponding to about 36 nsec of delay. We consider it likely that this was responsible for the bulk of the phase wind and delay changes.

Bandpasses have somewhat strange amplitude shapes, similar to some strange shapes we saw in the VLA-only tests. This will have to be sorted out and fixed before we can hope to move toward an operational system. Bandpass plots will be made in AIPS when the data are available.

We have 3.5 hours of test time on Monday, December 7, and will hold a meeting today to decide our highest priorities for that time. Current thinking centers on doing software tests, characterizing the bandpass, getting fringes at all the other VLA/VLBA frequencies (which requires getting all the sidebands and LOs correct, a non-trivial task), and seeing if the Pie Town position error was responsible for the bulk of the delay change over

Subject: Apparent station delays at PT relative to VLA
Date: Tue, 08 Dec 1998 18:29:19 -0700
From: Jim Ulvestad <julvesta@arana.aoc.NRAO.EDU>
Organization: National Radio Astronomy Observatory
To: ksowinsk@cv3.cv.nrao.edu, rberesfo@cv3.cv.nrao.edu
CC: julvesta@cv3.cv.nrao.edu, cwalker@cv3.cv.nrao.edu

Approximate delay measurements for PT, after 5-GHz delay is found and set to about 0 nsec, all relative to a single VLA antenna while observing 3C 345:

1.5 GHz: -600 deg. in 50 MHz --> -33 nsec

5 GHz: 0 deg. in 50 MHz --> 0 nsec

8.4 GHz (LSB): -460 deg. in 50 MHz --> -26 nsec

15 GHz: +220 deg. in 50 MHz --> +12 nsec

22 GHz: +150 deg. in 50 MHz --> + 8 nsec

43 GHz: -300 deg. in 50 MHz --> -17 nsec

These are probably good to 1-2 nsec.

3C 454.3, 5 GHz: +30 deg. in 50 MHz -->1.5 nsec, measured at 2030 UT. Phase drift is 200 deg. in 7 minutes. This is about 2 hours after the delay was set on 3C 345. Total drift in 120 minutes would be about 9.5 cycles at 5 GHz, or about 1.9 nsec, consistent in magnitude with the accumulated error. In any case, this corresponds to a PT position error of only about 0.5 meters, rather than about 2-3 meters as we thought in real time.

It's possible that all the signs need to be reversed, of course.

- ju -

VLA Computer Memo xxx

The LO Chain and Round-trip-phase Corrections

K. Sowinski

December 22, 1986

I have expended some effort lately to understand the VLA local oscillator chain, and particularly to be able to construct the round-trip phase correction. With a great deal of help from Barry Clark, I think I now understand matters and set that understanding down here so I will know what to say when someone asks me about it some years hence.

There are several quantities related to the LO chain that need to be determined to properly run the fringe stopping module (L7). These are: the sign convention for the 10.1 MHz signal which modulates the LO phase; the net sideband; the "sky frequency", called here the signed sum of the LOs and, if the round-trip phase correction is to be applied, a multiplicative factor to convert a phase change at 600 MHz to a change of antenna visiblity phase. Some of these quantities must be preserved for other uses as well. This memo will derive these quantities and define the form in which they will be available to the online system; in carrying out the latter, it may delve deeper into jargon than reader will be comfortable with.

I present first a conceptual summary of the LO chain. There are five local oscillators in the signal path from feed to sampler:

1. First LO (F3, F2 or F12)
2. Second LO (L6)
3. IF Offset (Takes 1025/50 to 1325, 1425, 1575 and 1675)
4. Pre-baseband Mixer (Mixes the IFs with 1200(USB) or 1800(LSB))
5. Fluke derived (Takes the IFs to baseband; C and D are LSB)

Following Barry's notes I define:

f_n = Frequency of Local Oscillator n (negative frequency is taken to mean up-conversion)

s_n = Sideband of LOn (± 1)

ϕ_n = Phase of Local Oscillator n

ψ_n = Phase of IF after mixing with LO n

We must remember that all these quantities must be defined independantly for each of the four IFs.

Typical values of 'f' and 's' for each IF at 6cm might be:

freq	A	B	C	D	s	A	B	C	D
1	0	0	0	0		1	1	1	1
2	3860.1	3810.1	3860.1	3810.1		1	1	1	1
3	-300	-400	-550	-650		1	1	1	1
4	1200	1200	1800	1800		1	1	-1	-1
5	100	200	250	150		1	1	-1	-1

The values of f_3, f_4, s_2, s_3 s_4, and s_5 are fixed by the design of the LO system; s_4 and s_5 are -1 for IF C and D, the remainder of the s_n are $+1$. The values of f_1, f_2 and f_5 are controlled by the LO card. The values of s_1 depend on observing band and are -1 at XX band and UU band. In the case of the alternate input signal path used at low frequencies we will, by convention, take $f_1 = 0$ and $f_2 = -(L6 - 3000)$.

We can now write the signed sum of the LOs and the frequency of the IF relative to the waveguide channel carrier:

$$f_{SSLO} = f_1 + s_1 f_2 + s_1 s_2 f_3 + s_1 s_2 s_3 f_4 + s_1 s_2 s_3 s_4 f_5$$

$$f_{WG} = f_4 + s_4 f_5 + s_4 s_5 f_{BWH}$$

where f_{BWH} is one-half the bandwidth.

Suppose now, that from the 600 MHz round-trip phase measurement we derive a path length change of D seconds in the waveguide, then:

$$\begin{aligned}
\phi_1 &= f_1 D \\
\psi_1 &= -s_1\phi_1 = -s_1 f_1 D \\
\phi_2 &= f_2 D \\
\psi_2 &= s_2(\psi_1 - f_2 D) = -s_2 D(f_2 + s_1 f_1) \\
\phi_3 &= f_3 D \\
\psi_3 &= -s_3 D(f_3 + s_2 f_2 + s_1 s_2 f_1)
\end{aligned}$$

And after coming back through the waveguide:

$$\psi_3 = -s_3 D(f_3 + s_2 f_2 + s_1 s_2 f_1) + f_{WG} D$$

f_4 goes through the waveguide twice before being used to mix down the IF:

$$\begin{aligned}
\phi_4 &= 2f_4 D \\
\psi_4 &= -s_4 D(2f_4 + s_3 f_3 + s_2 s_3 f_2 + s_1 s_2 s_3 f_1 - f_{WG}) \\
\phi_5 &= 0 \\
\psi_5 &= s_5 \psi_4
\end{aligned}$$

Let $s_{net} = s_1 s_2 s_3 s_4 s_5$ be the net sideband, and we know $s_n = 1/s_n$

$$\begin{aligned}
\psi_5 &= -s_{net} D(f_1 + s_1 f_2 + s_1 s_2 f_3 + 2s_1 s_2 s_3 f_4 - s_1 s_2 s_3 f_4 - s_1 s_2 s_3 s_4 f_5 - s_1 s_2 s_3 s_4 s_5 f_{BWH}) \\
&= -s_{net} D(f_{SSLO} - 2s_1 s_2 s_3 s_4 f_5 - s_{net} f_{BWH})
\end{aligned}$$

Then,

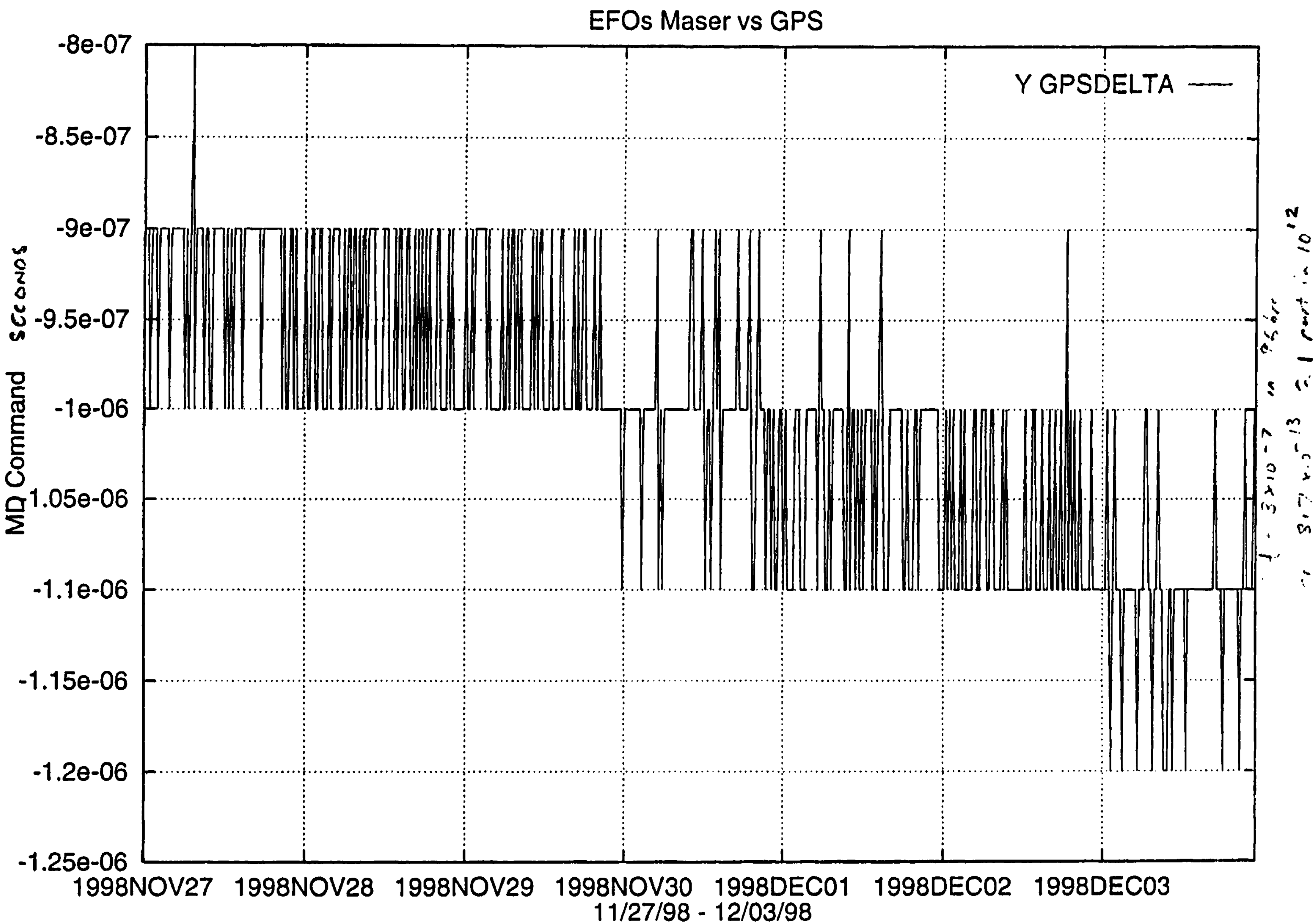
$$\phi_{corr} = \frac{\phi_{rt}}{1200}(s_{net} f_{SSLO} - 2s_5 f_5 - f_{BWH})$$

is the correction to be applied given a round-trip phase measurement ϕ_{rt}.

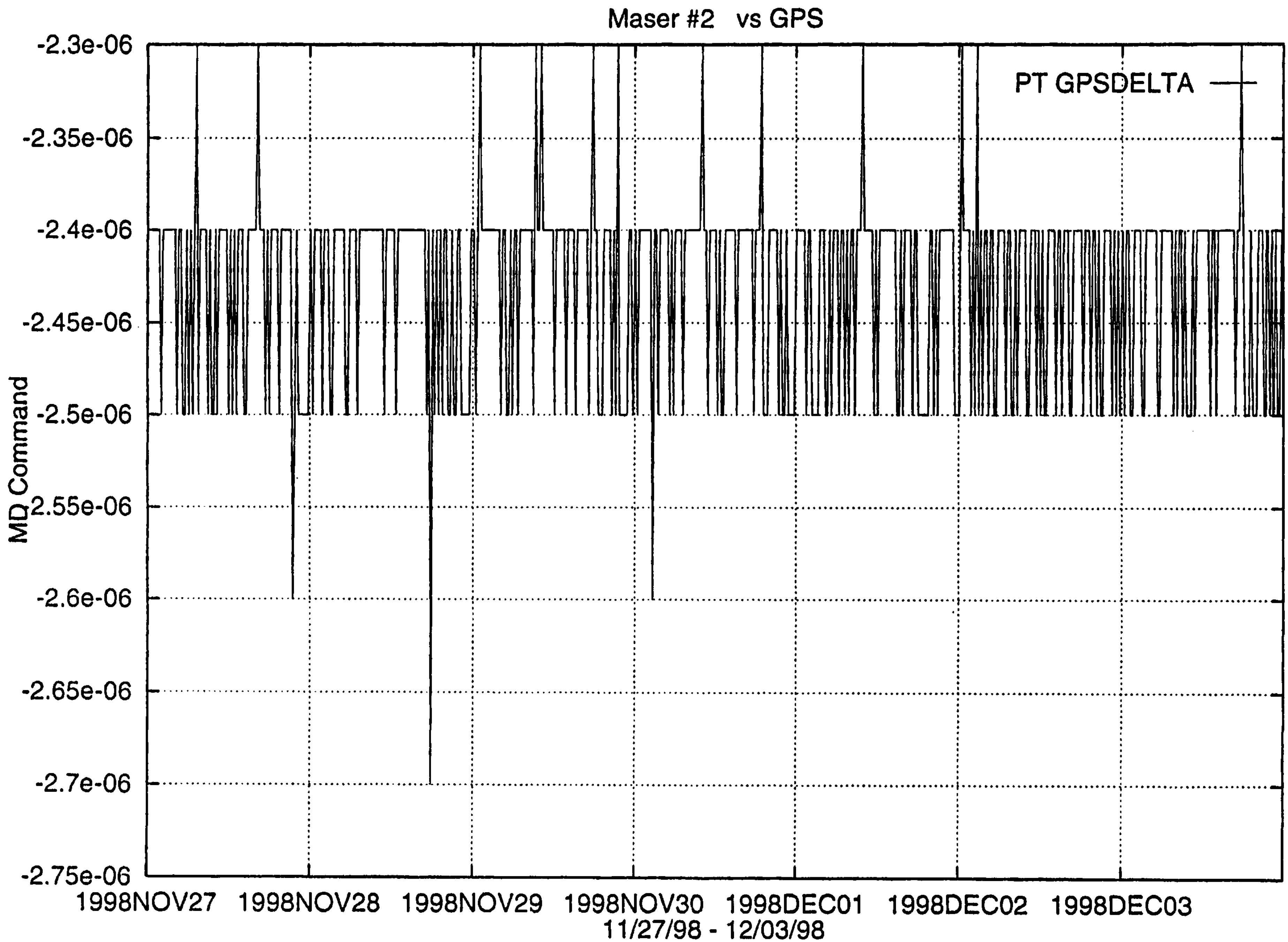
The round-trip phase correction is combined with the calculated geometric interferometer phase and applied along with the phase rate to the L7 module. This produces a 10.1 MHz signal modulated with the phase information to be used by the L6 to produce $f_2 = n50 \pm 10.1$ MHz. The sign of the phase derivative is given by:

$$s_{fringe} = s_1 sign(f_2) sign(10.1\,\text{MHz})$$

To drive the L7 we must maintain s_{fringe} and f_{SSLO} for each IF; in addition ϕ_{corr}/ϕ_{rt} is required to perform the round-trip phase correction.



f: 5000000.000004 Hz.


Maser #2 vs GPS
PT GPSDELTA
MD Command
-2.3e-06
-2.35e-06
-2.4e-06
-2.45e-06
-2.5e-06
-2.55e-06
-2.6e-06
-2.65e-06
-2.7e-06
-2.75e-06
1998NOV27
1998NOV28
1998NOV29
1998NOV30
1998DEC01
1998DEC02
1998DEC03
11/27/98 - 12/03/98

VLA/PT LINK POWER SUPPLY REQUIREMENTS

	SUPPLY RAIL VDC				
	2A's	9A's	10A's	2A's	2A's
Mod/Loc	**28**	**15**	**5**	**-5**	**-15**
PIE TOWN					
AB M4		10	3600		30
DS M1		*50*	*2400*		*50*
x2		100	4800		100
L1	600	180			
L2	620	130			30
L6	*260*	*360*	*1100*	*220*	*210*
x4	1040	1440	4400	880	840
L7		*40*	*1600*		
x2		80	3200		
L8			620		40
F4		*170*	*20*		*55*
x4		680	80		220
SWITCH	250		250		
Analog FO		*170*	*2000*	*400*	*170*
TX x2		340	4000	800	340
Digital FO Rx/Tx		510	4000	400	170
Total *current ma*	**2510**	**3470**	**24950**	**2080**	**1770**
VLA					
CB M3		30	3600		60
DCS M12		10	3600		30
Analog FO		*300*			
Rx x2		600			
Digital FO Rx/Tx		510	4000	400	170
SWITCH	250		250		
Total *current ma*	**250**	**1150**	**11450**	**400**	**260**

Ron Beresford 16Dec97

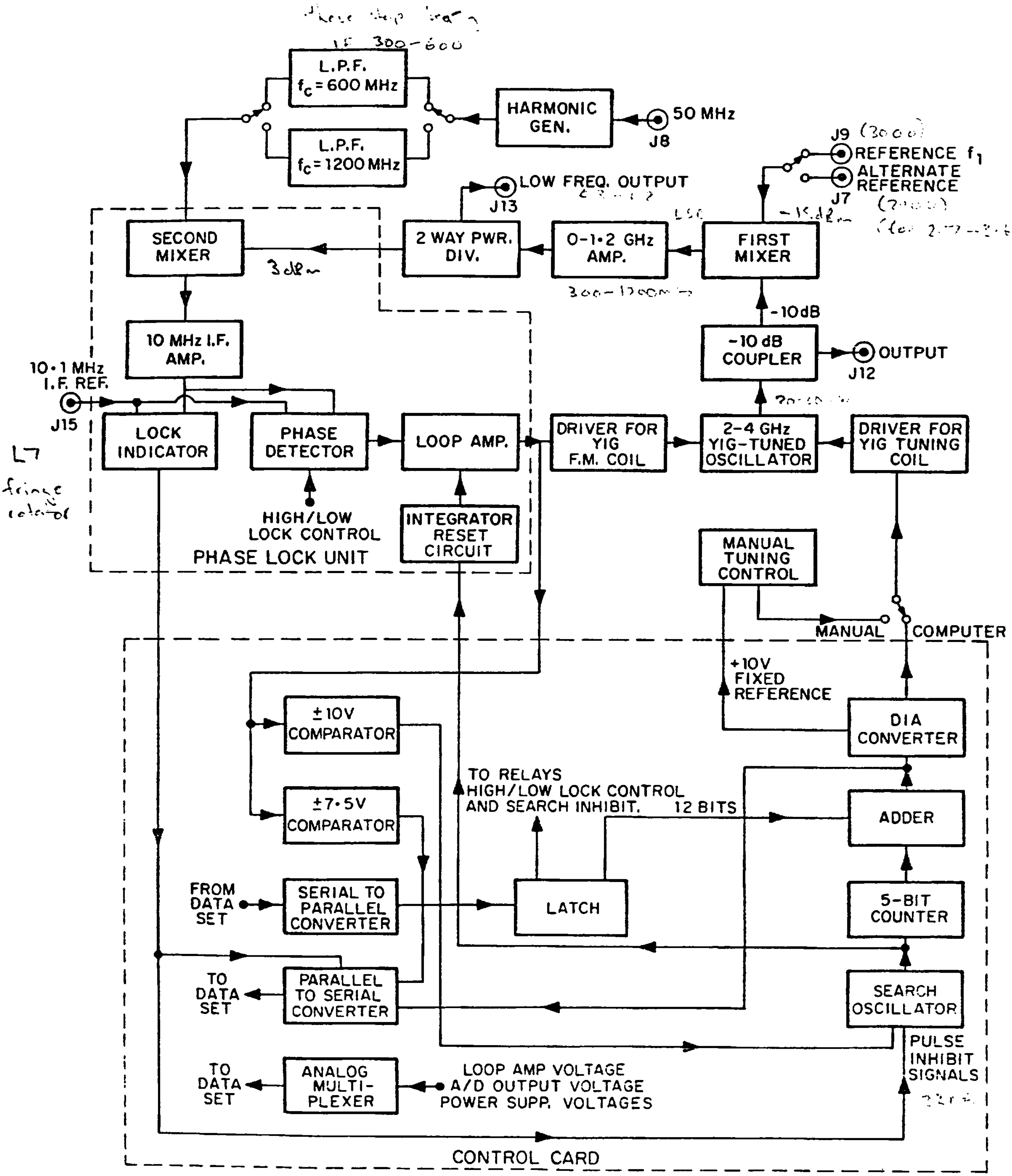
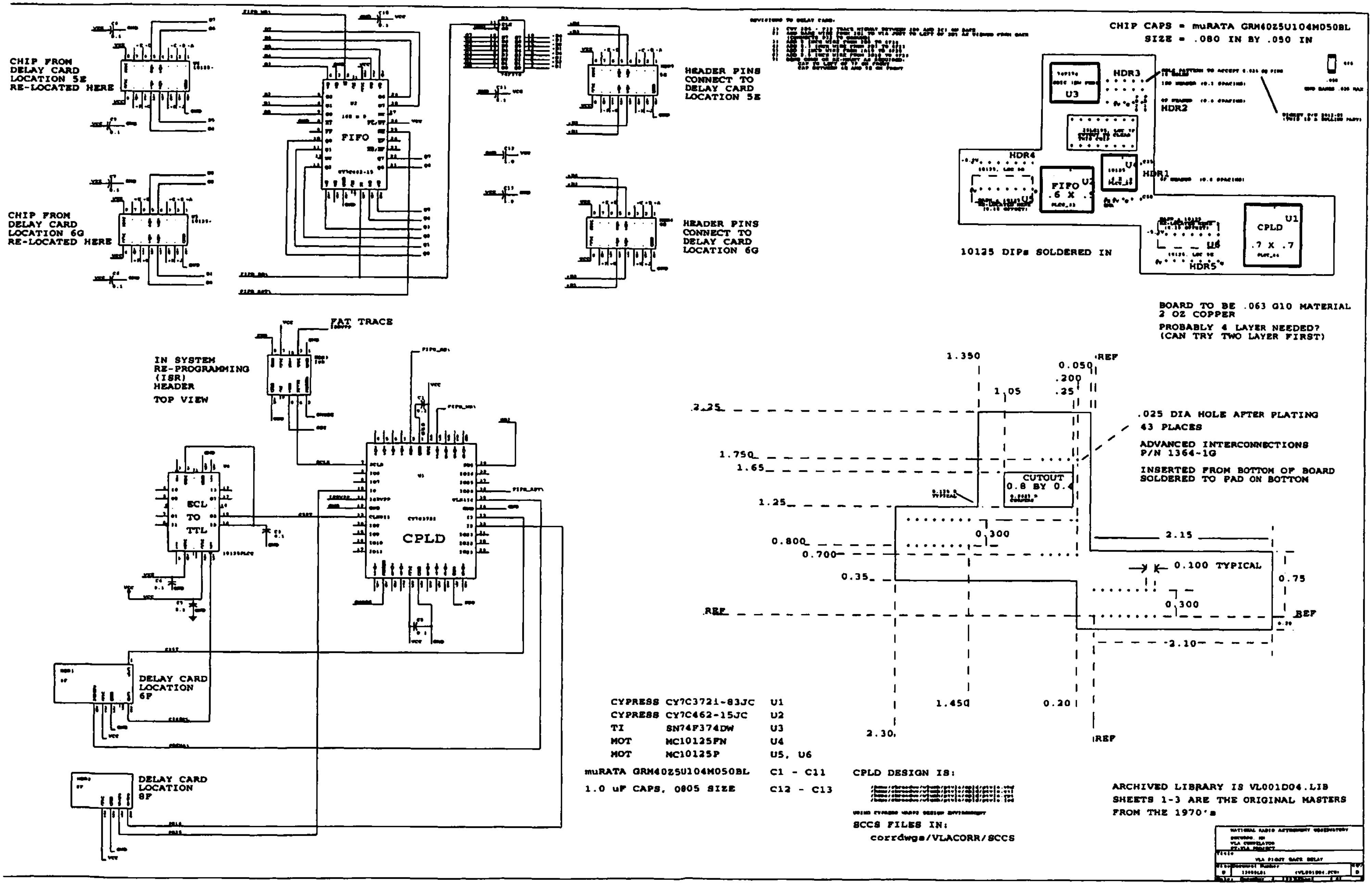
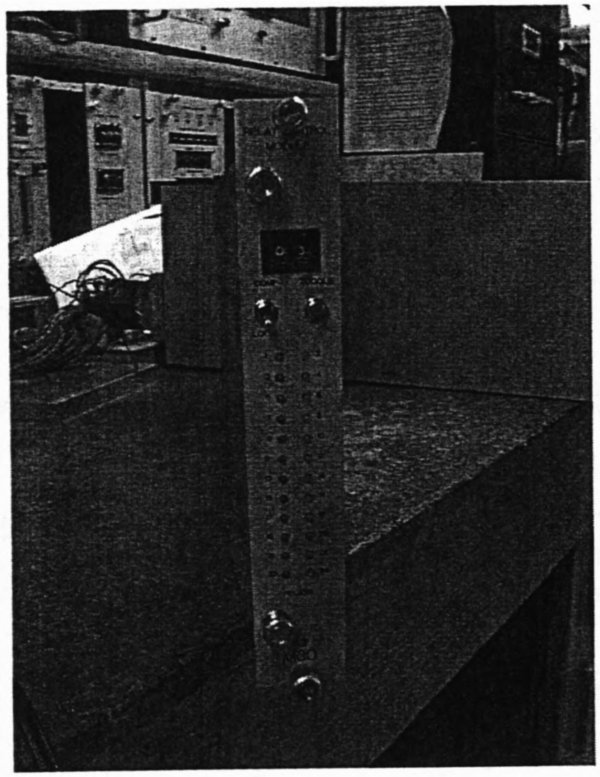


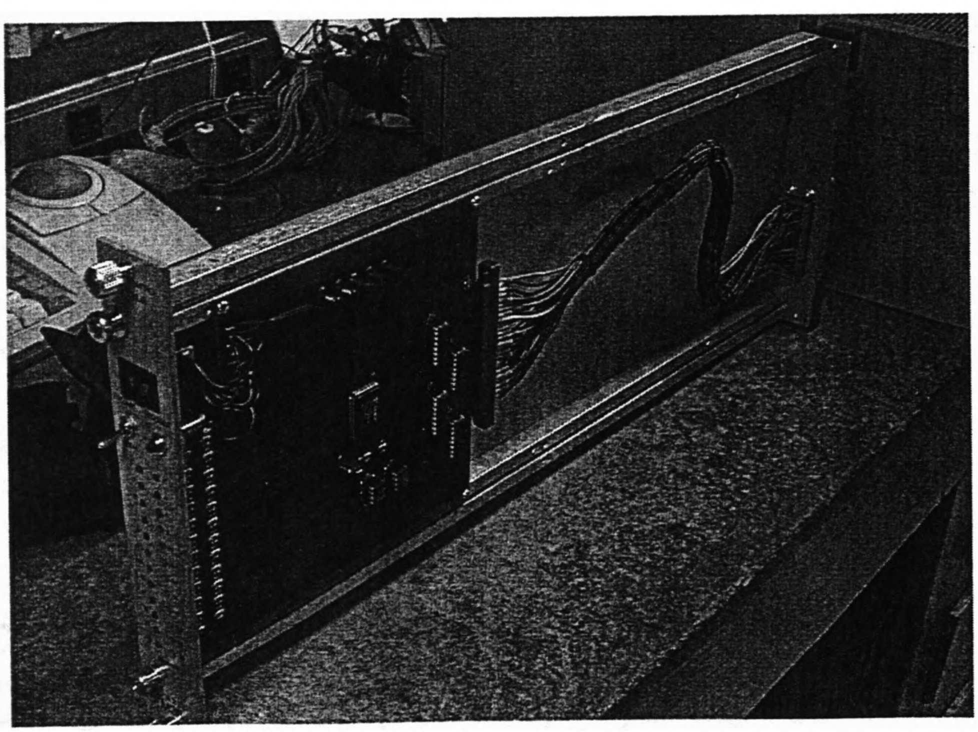
Fig. 1. Block diagram of 2-4 GHz synthesizer.



CHIP FROM DELAY CARD LOCATION 5E RE-LOCATED HERE
CHIP FROM DELAY CARD LOCATION 6G RE-LOCATED HERE
FIFO
HEADER PINS CONNECT TO DELAY CARD LOCATION 5E
HEADER PINS CONNECT TO DELAY CARD LOCATION 6G
CHIP CAPS = muRATA GRM40Z5U104M050BL
SIZE = .080 IN BY .050 IN
HDR3
U3
HDR2
HDR4
FIFO .6 X .5
U2
HDR1
U4
CPLD .7 X .7
U1
U6
HDR5
10125 DIPs SOLDERED IN
BOARD TO BE .063 G10 MATERIAL
2 OZ COPPER
PROBABLY 4 LAYER NEEDED?
(CAN TRY TWO LAYER FIRST)
FAT TRACE
IN SYSTEM RE-PROGRAMMING (ISR) HEADER
TOP VIEW
ECL TO TTL
CPLD
1.350
0.050
.200
.25
REF
1.05
2.25
.025 DIA HOLE AFTER PLATING
43 PLACES
ADVANCED INTERCONNECTIONS
P/N 1364-1G
INSERTED FROM BOTTOM OF BOARD
SOLDERED TO PAD ON BOTTOM
1.750
1.65
CUTOUT
0.8 BY 0.4
1.25
0.300
0.800
0.700
2.15
0.100 TYPICAL
0.75
0.35
0.300
REF
REF
2.10
1.450
0.20
2.30
REF
DELAY CARD LOCATION 6F
DELAY CARD LOCATION 8F
CYPRESS CY7C3721-83JC U1
CYPRESS CY7C462-15JC U2
TI SN74F374DW U3
MOT MC10125FN U4
MOT MC10125P U5, U6
muRATA GRM40Z5U104M050BL C1 - C11
1.0 uF CAPS, 0805 SIZE C12 - C13
CPLD DESIGN IS:
SCCS FILES IN:
corrdwgs/VLACORR/SCCS
ARCHIVED LIBRARY IS VL001D04.LIB
SHEETS 1-3 ARE THE ORIGINAL MASTERS
FROM THE 1970's

M30 RELAY CONTROL MODULE





SCIENCE RESULTS

First Images on VLA - Pie Town Link

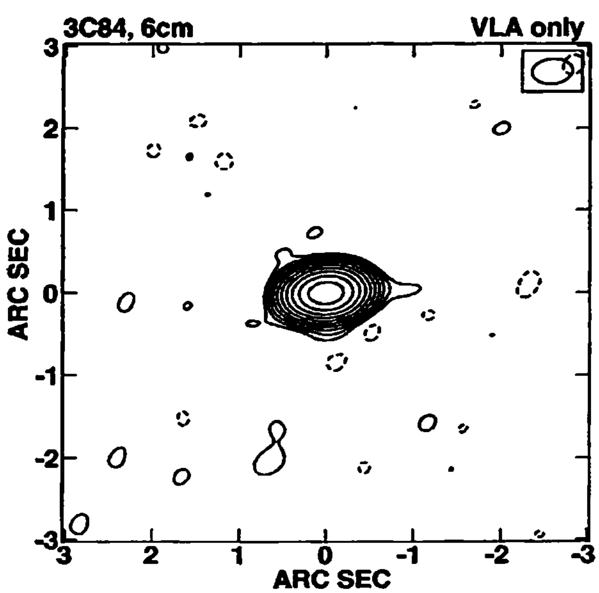
The VLA-Pie Town real-time link has recently obtained its first images, following the first fringes reported in NRAO Newsletter No. 78 (1 January 1999). On August 12, 1999, fringes were detected from Pie Town (PT) to all the antennas of the VLA in 2 IF bands (the AC IF pair), with the VLA in the A configuration. Along with test data of various types, a 30-minute snapshot was obtained on the radio galaxy 3C84 at 6 cm wavelength. A "first image" using the VLA+PT was made from this observation; the source was completely unresolved, with the synthesized beam reduced by nearly a factor of two in east-west extent. (A full synthesis track is required to obtain the best two-dimensional resolution.) The dynamic range for the VLA+PT image is as good as that for the VLA-only image, well over 10,000:1 with rudimentary self-calibration, indicating that phase-closure errors are quite small. The first image is shown below; further information and (u,v) coverage can be accessed at http://www.nrao.edu/~julvesta/vlapt_dir/first-images.html.

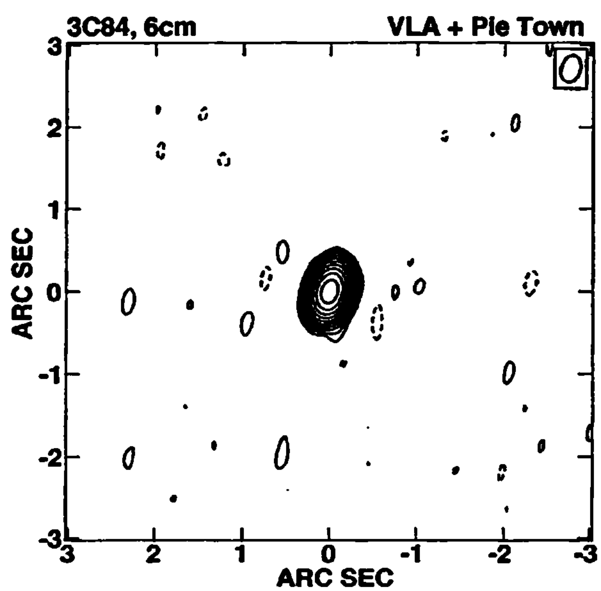
In August and September 1999, the first scientific observations were made with the VLA+PT. Four projects selected by the Scheduling Committee were observed; all were mainly spectroscopic observations. The first science observation using VLA+PT was a project to study redshifted HI absorption toward the gravitational lens PKS 1830-211, at a frequency of 1191 MHz. This project (scientific investigators were Chris Carilli, Marc Verheijen, and Karl Menten) was observed on August 20, 1999, and was deemed very successful, resolving the HI absorption components against the two main sources in the gravitational lens. Results from the other three science projects are pending. These scientific observations made use of translator software written by Barry Clark, which converts a VLA observing file into the file format needed for the Pie Town VLBA computer to operate the antenna and frontends at PT.

During the next several months, the final design of the link hardware will be implemented and tested. Included in this design and implementation will be a full 4 IF capability. Testing and characterization of the phase stability of the link, as well as testing and implementation of phase-correction algorithms, will be performed. Development of necessary user calibration techniques as well as definition of operational requirements will also be a focus of the near-term future. Full operation of the link as a user facility is expected for the next VLA A configuration in the fourth quarter of 2000. NRAO plans to advertise the official availability of the VLA-PT link well in advance of the June 1, 2000, proposal deadline for that configuration.

NRAO would like to give a special acknowledgment to project engineer Ron Beresford, who is responsible for the design and much of the implementation of the fiberoptic connection hardware at Pie Town and the VLA. Ron has been in Socorro since June 1997, on leave from the Australia Telescope National Facility, and will be returning to Australia near the end of this year.

M. J. Claussen and J. S. Ulvestad





Status of VLA Q-band (7 mm) Receivers

Additional antennas equipped with 7 mm receivers will become available for the upcoming VLA configurations. Until recently, only 13 of the 27 VLA antennas were equipped with Q-band (7 mm) receivers. Starting in August 1999, new Q-band receivers are being installed on other VLA antennas. Antennas 18, 19 and 21 will be out fitted with new receivers by mid October 1999. Three more antennas are expected to be equipped by the end of the year, bringing the total number of antennas with Q-band receivers to 19. If things proceed as scheduled, then we expect 25 VLA antennas to be equipped with Q-band receivers by the end of 2000.

K. R. Anantharamaiah

Engineering Services Status

Engineering has embarked on a project which promises to be the most significant hardware improvement to VLA antenna blind pointing since the yoke and major structural members were insulated in the mid 1980s. Currently, electronics for the Inductosyn absolute position encoders used on the VLA permit cyclical excursions of several arcseconds in pointing accuracy. In addition, an unreliable overlap between coarse and fine encoding causes frequent telescope failure. The new electronics are expected to reduce the cyclical errors to the subarcsecond level and eliminate the unreliable overlap problem altogether. Additional bits in the new encoder system will provide higher resolution in measuring absolute position and provide improved reliability in detecting the state of the azimuth cable wrap-up.

A prototype of the new encoder electronics has been installed on Antenna 24 for evaluation and is working satisfactorily. Together with mechanical projects such as improved encoder couplings and replacement of failed azimuth bearings, the new encoder electronics project is expected to lead to 6 arcsecond blind pointing on the VLA antennas. Ten arcsecond pointing is the current mean. The project may also have important implications for VLBA pointing improvements since the same type of absolute position encoders are used for the VLBA antennas. The design is based on earlier encoder electronics work at the UA/SAO MMTO. More information is available in VLA Test Memo 218 or e-mail bbroilo@nrao.edu.

C. C. Janes and B. M. Broilo

New Mexico Computing Developments

After one year of centrally administered Linux support, the AOC has now approximately 40 workstations and laptops running this operating system. Thirty of these are new purchases, and ten are machines that used to be running Windows. Nearly all standard software packages available under Solaris have been installed for use under Linux. These packages include AIPS, AIPS++, IRAF, miriad, gipsy, sched and jobserve. For the foreseeable future, we intend to continue full local support for both Solaris and Linux.

We are completing our preparations for dealing with the Y2K bug. We intend to complete the final phases of ensuring operating system Y2K compliance over the next few months. All SGI systems have been upgraded to IRIX 6.5.3. All Sparc systems at both the AOC and VLA will be upgraded to Solaris 2.6, and the Linux systems will be upgraded to Redhat 6.0. All system upgrades should be completed by early November at the latest. At the VLA site, the operating system for the VLA control computers has now been updated with the Y2K patches. Y2K compliant application software was installed during the September update of the VLA online software.

The AOC help desk has been in existence since the beginning of July. During the first 2.5 months, approximately 200 requests were received, 130 of those requests have been resolved. Many of the remaining requests are long term projects. The help desk is staffed Monday through Friday 9 a.m. to 12 p.m. and 1 p.m. to 4 p.m. The office may be reached at (505) 835-7213. Requests may be submitted either by sending mail to helpdesk@aoc.nrao.edu or by filling out the form on http://helpdesk.aoc.nrao.edu. Users can track the status of their own and other outstanding items on the web as well. We feel that the introduction of the help desk has improved feedback to the users ,and at the same time, allows more efficient use of the systems administrators' time.

Testing of the new VLA correlator controller has begun. This system will eventually replace the VLA correlator system controller, a Modcomp computer, and the Array Processor. Enough hardware and software is now complete to allow initial testing at the VLA site. The VLA expansion computing team is defining system requirements, evaluating technology, and developing a computing plan. Development of an interface to the VLA monitor and control system was begun. This interface will be used by the new control system during the transition from current to modified VLA antennas, and as a test bed for the VLA expansion computing design.

A prototype of a computer system which will deliver geometric delays for the VLA Upgrade and the VLBA correlator has been built. This model server is built on Goddard Space Flight Center Calc version 9.1 and runs on an independent computer. Requests from the instruments for delays come over a network connection. The prototype is under test with the VLBA correlator.

G. A. van Moorsel

Submitted this 10/22/99

Please proofread this information

The following is a LaTeX to HTML translation of the abstract information you entered for the AAS Meeting #195. This partial translation is how your abstract will appear online. The LaTeX in your abstract will be fully translated in The Bulletin of the American Astronomical Society (BAAS).

Please proof it and press the COMMIT button on the bottom of this form.

The Optical-Fiber Transmission Link Between the VLA and the Pie Town VLBA Station

M. J Claussen, R. Beresford, K. Sowinski, J. S. Ulvestad (NRAO)

We report on the implementation of a 104-km fiber-optic link between the NRAO's VLA and the Pie Town (NM) VLBA antenna (Pt), in order to transmit analog intermediate frequency (IF) and local oscillator (LO) signals, and also to transmit digital monitor and control signals to and from the two instruments. The IF signal from the Pt antenna is successfully returned to the VLA over the fiber-optic link, and is fed into the real-time correlator, where it is treated just as any other VLA signal (except for the larger delay). Using the VLA-Pt link, the angular resolution of the VLA can be effectively doubled for objects in much of the sky, while maintaining the full sensitivity of the 27-antenna VLA. We will describe the details of the link and its implementation, and show the first images made with the link operating. We expect full operation of the VLA-Pt link as a user facility to be available in the next A configuration during the last quarter of 2000. NRAO's proposal deadline for that configuration will be 1 June 2000.

The success of the VLA-Pt link is founded on the efforts of a large number of individuals at The National Radio Astronomy Observatory. The NRAO is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

Presentation Type: display
Category: 27. Instrumentation: Ground Based or Airborne

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Presentor phone: 505-835-7284
Correspondent address: NRAO P.O. Box O Socorro, NM 87801

Supplemental email: mclausse@nrao.edu

If the information is correct, press the "Commit" button below. If the information is *not* correct, please use the **Back** button on your browser to return to the input form and correct the problem.

When you are satisfied with your submission, please print this page for future reference.

ing self-organization, they displaced silver atoms and formed islands of sulfur embedded in the silver sheet. The strain on the silver sheets caused them to distort to accommodate the sulfur islands and caused the flat ruthenium substrate underneath to warp slightly into the shape of a cup. These distortions caused the sulfur islands to repel each other and organize into an ordered pattern.

Once the lattice pattern had been formed, researchers were able to obtain the elastic constants of the lattice. This was done by measuring the thermal fluctuations of the centers of mass of each vacancy island. They also were able to quantify the weak forces responsible for the lattice's stability.

According to researchers, those were roughly 10,000 times less than the electrical forces that operate at close range between atoms. These results are consistent with general theories of strain-mediated interactions between surface defects in strained films.

The discovery and quantifying of these forces may give researchers the clues they need to control and tune the pattern-forming interactions to create specific patterns. This is significant because of the extreme difficulty associated with patterning at such small scales. The substrate distortion produced by the self-organization phenomenon could lead to a way to make ordered arrangements.

The nanopattern research team recently received additional funding from Sandia Labs to try to determine how general the self-organizing phenomenon is, and whether it can be applied to other metals.

For more information on the ongoing research and experimentation into nanopatterns, check out the Sandia web site at *www.sandia.gov*.

Cheryl Ajluni

Fiber-Optic Link Provides Radio Telescopes A Four-Fold Increase In Image Detail

Scientists and engineers at the National Radio Astronomy Observatory (NRAO) in Socorro, N.M., have demonstrated the longest fiber-optic data link ever used in radio astronomy. The 65-mile link connects two National Science Foundation (NSF) facilities—the Very Large Array (VLA) radio telescope in Socorro, and an antenna of the continent-wide Very Long Baseline Array (VLBA) system in Pie Town, N.M.

The link will allow scientists to use the two NSF facilities together in real time. It's also the first step toward expanding the VLA to include eight proposed new antennas throughout New Mexico. The project, funded by the NSF and Associated Universities Inc., links the VLA and the VLBA antennas through a Western New Mexico Telephone Co. fiber-optic cable.

"Linking the Pie Town antenna to the VLA quadruples the VLA's ability to make detailed images of astronomical objects," said Paul Vanden Bout, NRAO's director. "This alone makes the link an advance for science, but its greater importance is that it clearly demonstrates the technology for improving the VLA's capabilities even more in the future."

The VLA is a system of 27 radio-telescope antennas distributed over the high desert west of Socorro in the shape of a giant "Y." Made famous in movies, commercials, and numerous published photos, the VLA has been one of the most productive and versatile astronomical observatories in the world since its dedication in 1980. The VLBA consists of 10 radio telescopes distributed across the continental United States, Hawaii, and St. Croix in the Caribbean.

The cosmic radio waves received by each antenna in the VLA and VLBA are combined with those received by every other antenna in the system. This produces images with extremely high resolution. The more widely separated the antennas, the greater the resolving power. The greatest separation between antennas in the VLA is 20 miles; in the VLBA, it's 5000 miles.

Yet, because of the way in which such multi-antenna radio telescopes, called interferometers, work, a gap exists between the levels of detail obtainable with the VLA and the VLBA. Linking the VLA to the VLBA Pie Town antenna is the first step toward filling in that gap and allowing astronomers to see structures of any scale—small, medium, or large—in objects such as stars, galaxies, and quasars. The eight additional proposed antennas would close that gap.

Adding the new antennas to the VLA "would provide the capability to image astronomical objects on all spatial scales, from the very largest to the very smallest," says Vanden Bout. "The combination of the VLA and VLBA then would be the only single instrument in astronomy covering such a range of spatial scales."

Authorized by Congress in 1972, the existing array of antennas was built from 1974 to 1980. The additional antennas are part of a comprehensive plan that the NRAO developed for upgrading the VLA. Replacement of the original, 1970s-era electronic equipment also is included. The refurbishment will improve the VLA's scientific capabilities from tenfold to a hundredfold in all research areas. For a modest investment, it also would provide an enhanced facility many times more powerful than the original VLA.

"Though the VLA today is hundreds of times more capable than its original design, some of the technologies of the 1970s that still are in use threaten the instrument with premature obsolescence," said Miller Goss, NRAO's director of VLA/VLBA operations. "Replacing those with today's technology will ensure the VLA's continued role as one of the world's premier astronomical research facilities."

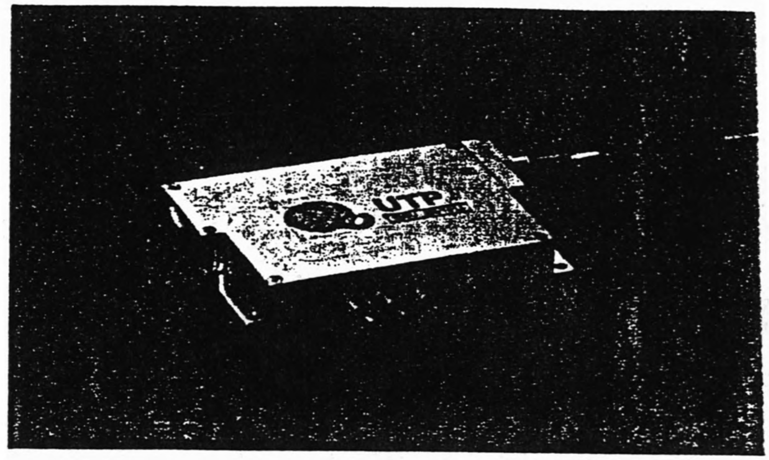
The link project involved designing, building, and testing specialized electronic equipment to connect the VLA and the Pie Town antennas to the fiber-optic cable. Additionally, hardware and software at the VLA was modified to allow using the Pie Town antenna as an integral part of the VLA. "This was an extremely complex undertaking, and it succeeded because of an outstanding team effort involving scientists, engineers and technicians," Goss said.

For more information, contact the National Radio Astronomy Observatory, P.O. Box O, Socorro, NM 87801, or visit its web site at *www.nrao.edu*.

Joseph Desposito

DATA SHEETS

RF Fiber-Optic Small Integrated Receiver Unit (SIRU)



Applications

- Cellular And PCS Antenna Remoting
- Microwave Delay-Lines
- Precise Frequency-Distribution Systems
- Radar System Calibration
- Phased Array Antenna Systems

Features

- Integrates a high-frequency photodiode into a ruggedized package
- 0.01 - 3 GHz bandwidth
- Photocurrent monitoring circuit

Specifications (SIRU1114)

Physical

Configuration .... Environmentally-sealed unit.
Dimensions .... 0.61" H x 3.25" W x 2.25" D
Custom Configurations Available
Operating/ Storage Temperature ... -40 °C to + 70 °C

Electrical

Frequency Range (see plots) ...... 10 MHz to 3 GHz
Electrical Power Requirements .... + 15 V @ 0.25 A
Photocurrent monitor output ..... 1 V/mA
RF Connector .... SMA (female)

Optical

Wavelength .... 1300 - 1600 nm
Connectors .... Diamond AVIM, angle-polished
Optical Input Power .... + 3 dBm maximum
Responsivity at DC .... > 0.85 A/W
Internal matching impedance ...... 500 Ω

uniphase
telecom products (UTP)

UNIPHASE TELECOMMUNICATIONS PRODUCTS
TRANSMISSION SYSTEMS DIVISION

Direct Modulation SIRU FINAL ATP RESULTS

Model Number: SIRU1114
Serial Number: 2027
Environment: Ambient Temperature Testing

PhotoDiode (PD) Current:	.894 [mA]	Note 1
PD Monitor Voltage:	.921 [V]	Note 1
PD Monitor Voltage:	.035 [V] 3.5 mV ?	Note 2
Frequency Response	See S21 Plot	Note 1
Bandwidth:	See S21 Plot	Note 1

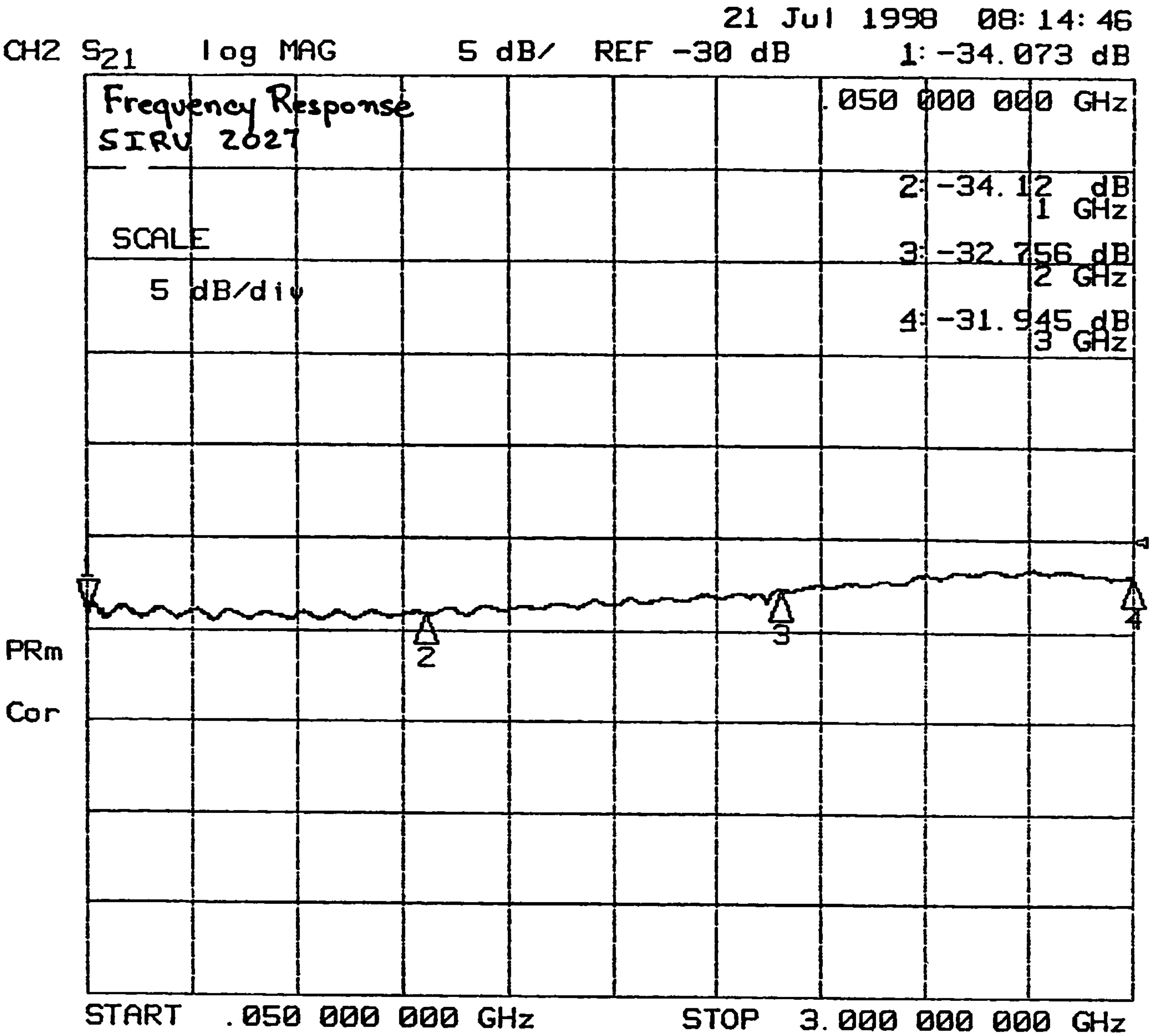
+15 Volt Power Supply Current 33 [mA]

for 0dBm (1000 uW) PD volts = 0.921
921 uV / uW

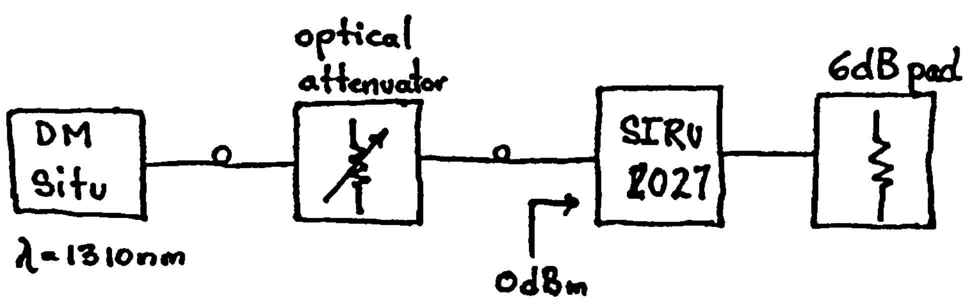
Operator: Darren W. Gray Date: 7-21-98

Notes:
1. Optical Input Power = 0 dBmo at λ = 1310nm
2. No Optical Input to Receiver
3. Optical Input Power = 0 dBmo at λ = 1550nm
4. Tested with Externally Modulated SITU

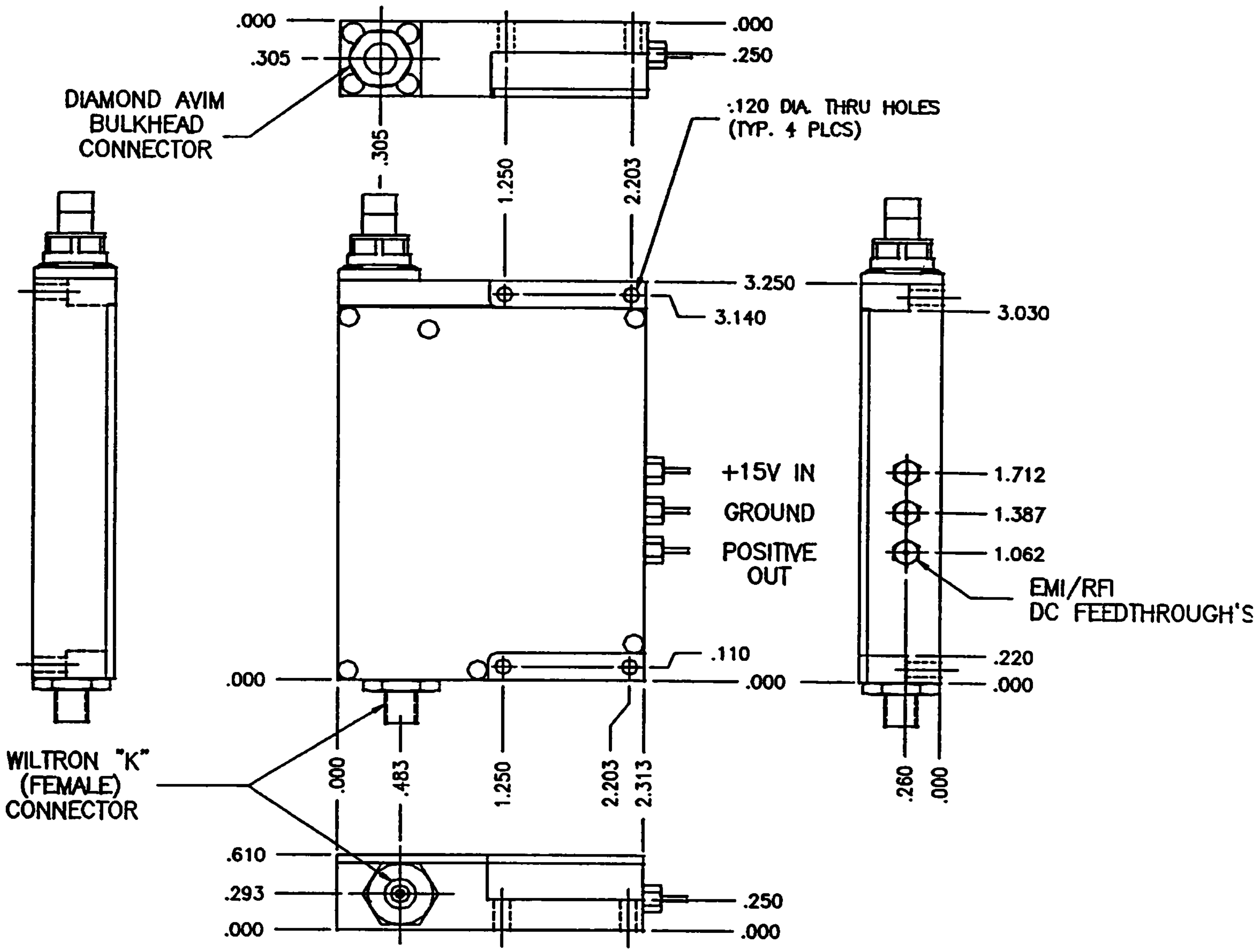
Post-Seal.



21 Jul 1998 08:14:46
CH2 S21 log MAG 5 dB/ REF -30 dB 1: -34.073 dB
.050 000 000 GHz
Frequency Response
SIRU 2027
SCALE
5 dB/div
2: -34.12 dB
1 GHz
3: -32.756 dB
2 GHz
4: -31.945 dB
3 GHz
PRm
Cor
2
3
4
START .050 000 000 GHz
STOP 3.000 000 000 GHz



DM
Situ
λ=1310nm
optical
attenuator
SIRU
2027
0dBm
6dB pad



.000
.305
DIAMOND AVIM
BULKHEAD
CONNECTOR
.000
.250
.120 DIA. THRU HOLES
(TYP. 4 PLCS)
.305
1.250
2.203
3.250
3.140
3.030
+15V IN
GROUND
POSITIVE
OUT
1.712
1.387
1.062
EMI/RFI
DC FEEDTHROUGH'S
.110
.220
.000
.000
.000
WILTRON "K"
(FEMALE)
CONNECTOR
.000
.483
1.250
2.203
2.313
.260
.000
.610
.293
.000
.250
.000

UTP

Final Test Data Sheet

Customer Name:	**Associated Universities Inc.**
Catalog Number:	**S5-150-1-1-C2-P1-I2-O2=S**
Part Number:	**S5150-001953**
Description:	**1550 nm 2.5 GHz MZM**
Job Number	**J1208**
Serial Number:	**81141E**
Sliver ID Number:	**8114-1-E**
Input Fiber Type:	**Fujikura SM-15-P-8/125-UV/UV-400**
Output Fiber Type:	**Fujikura SM-15-P-8/125-UV/UV-400**

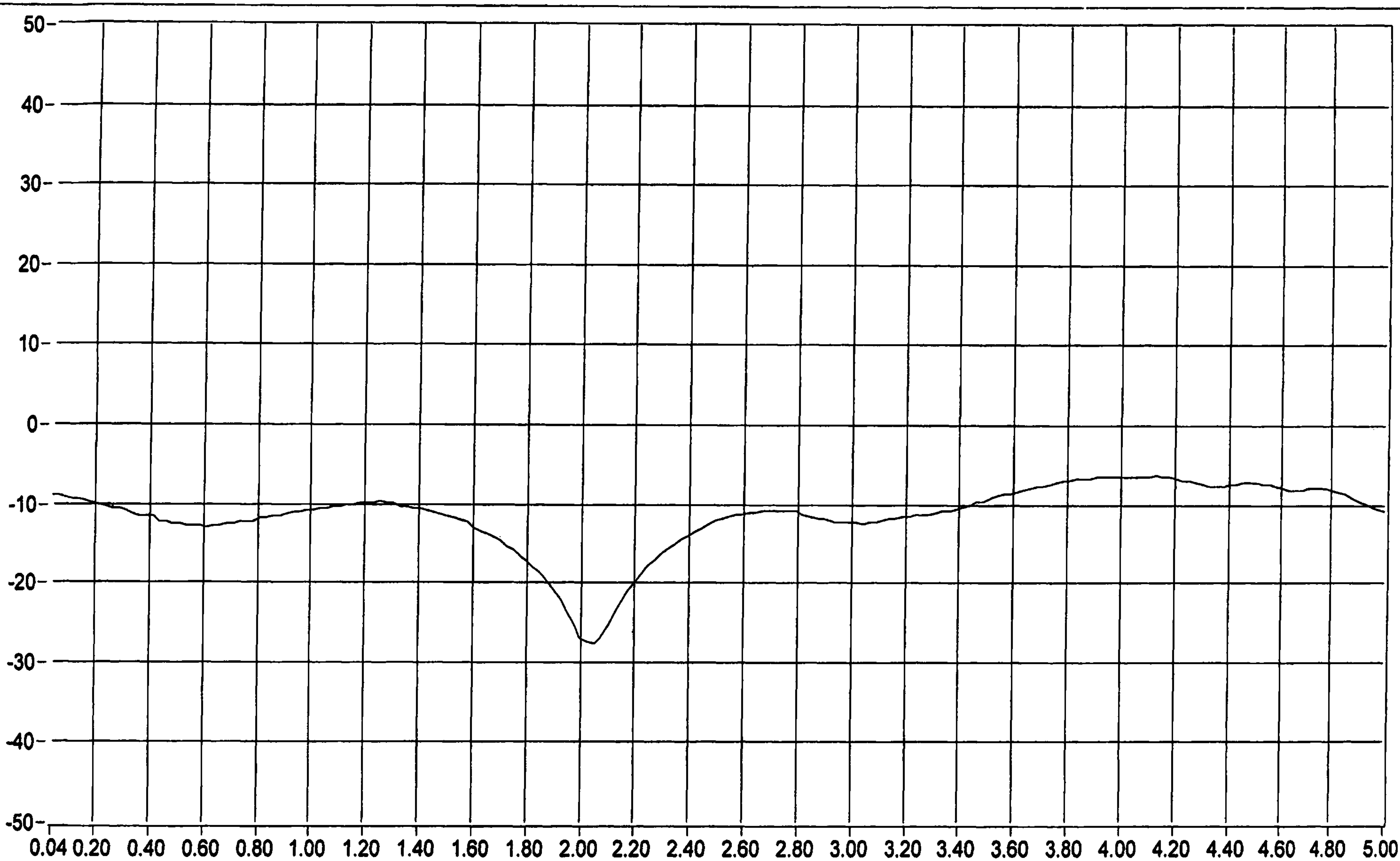
Optical Performance Parameters

Parameter	Value	Units
Insertion Loss:	3.8	dB
On/Off Extinction:	27.0	dB
Output Polarization Crosstalk:	21.8	dB
RF Electrode Half-wave Voltage:	2.9	V
Bias Electrode Half-wave Voltage:	4.2	V
Test Wavelength:	1553	nm
Source Type:	Laser Diode	

Electrical Performance Parameters

S_{11} (Return Loss) Plot Attached
S_{21} (Thru Loss) Plot Attached

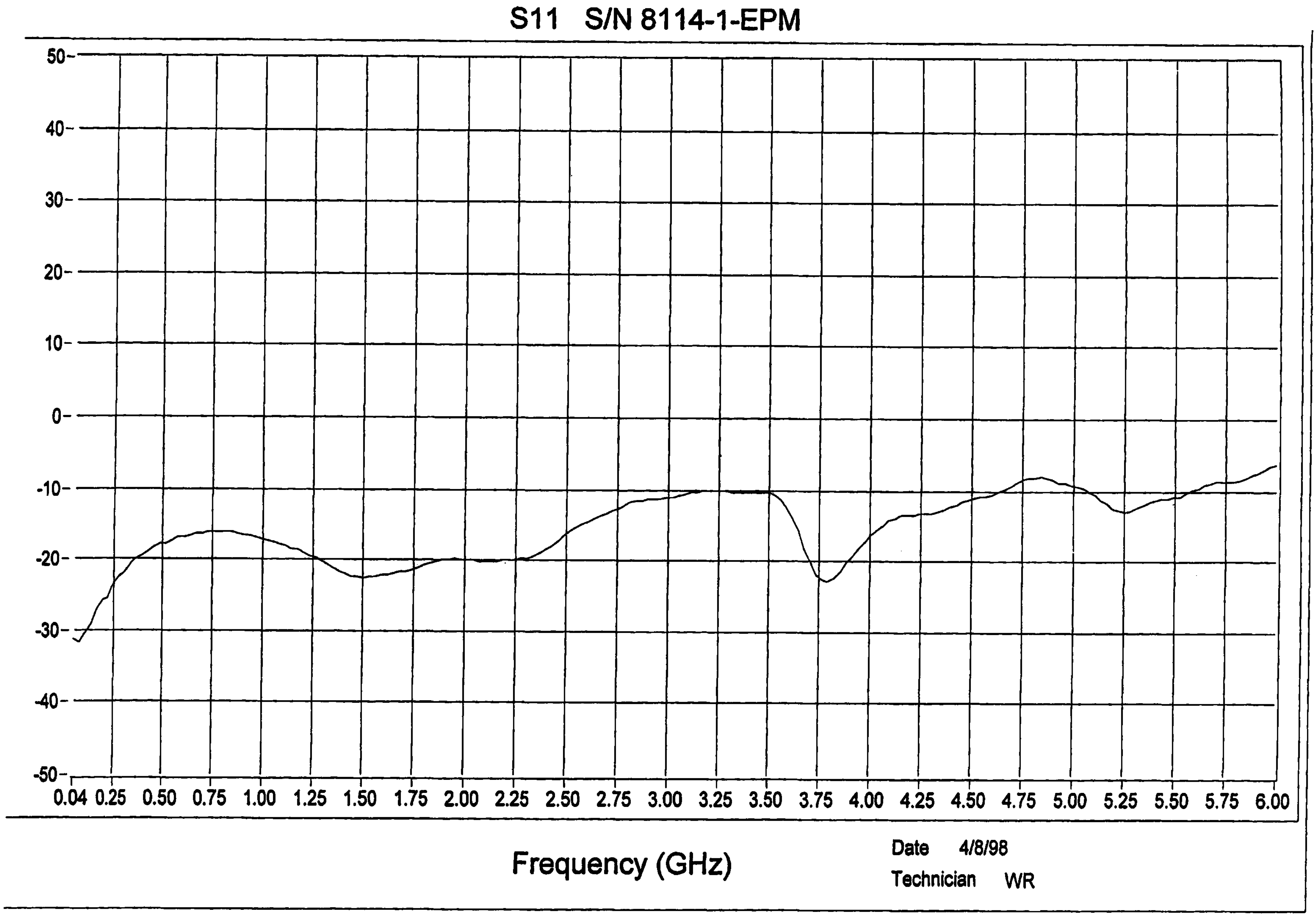
S11 S/N 8114-1-E



Frequency (GHz)

Date 4/8/98

Technician WR

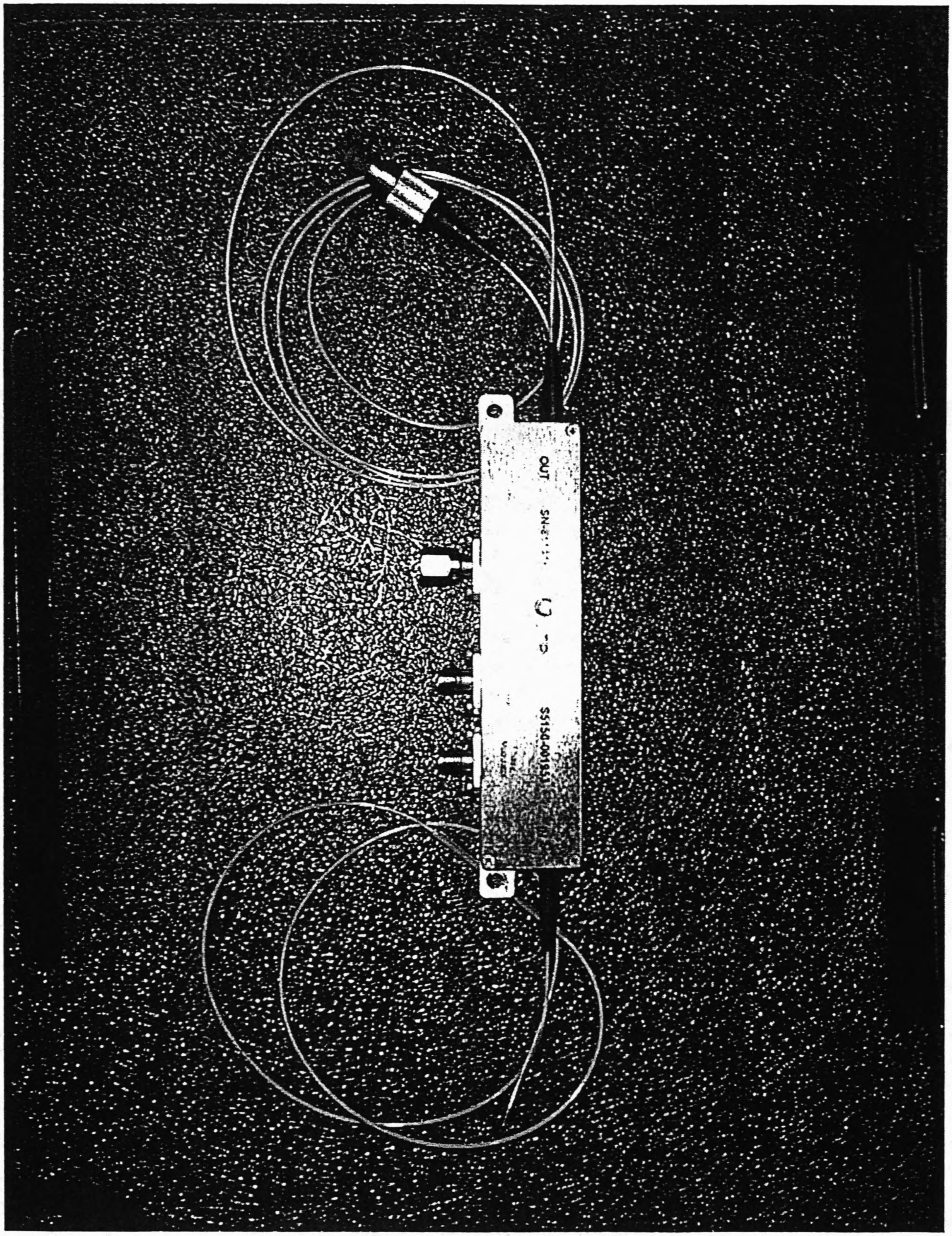

S11 S/N 8114-1-EPM
50
40
30
20
10
0
-10
-20
-30
-40
-50
0.04 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50 2.75 3.00 3.25 3.50 3.75 4.00 4.25 4.50 4.75 5.00 5.25 5.50 5.75 6.00
Frequency (GHz)
Date 4/8/98
Technician WR

S21 S/N 8114-1-E

Frequency (GHz)

Date 4/8/98

Technician WR


OUT

****** PLEASE READ BEFORE OPERATING MODULATOR ******

Operating Instructions for Standard Uniphase Electro-optic Intensity Modulators

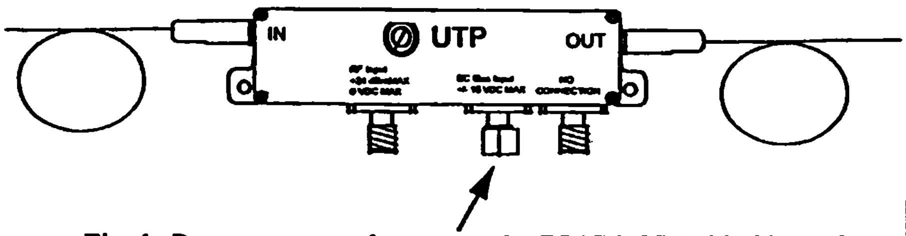


Fig. 1. ***Do not remove the cap on the BIAS PORT. No bias voltage is required for normal modulator operation.***

This part does not require a bias voltage under normal operating conditions.
This device is designed for operation with AC coupled signal sources. The zero volt operating point of this modulator has been set to half intensity (quadrature) during device fabrication as shown in Fig. 2.

Fiber Optic Connections to All Modulators:

- Connect the laser output fiber to the modulator input fiber. The input fiber is panda style polarization maintaining fiber. The polarization vector should be parallel to the fiber stress rods as shown in Fig. 3. If the modulator was purchased with an FC connector on the input fiber, the polarization vector should be aligned parallel to a line drawn through the key and the fiber core. Excessive optical loss will result if the polarization vector is not aligned properly with respect to the stress rods.
- The output fiber should be connected to a photodiode or other component. The output fiber is single mode; however, the light is polarized. In most applications, the orientation of the polarization at the fiber output does not affect system performance.
  Polarization maintaining fiber at the output port may be specified when a modulator is ordered if output polarization orientation is important in an application.

Digital Modulators: Electrical Connections

- The shorting cap should not be removed from the BIAS PORT. No voltage is required at this port.
- The electrical signal should be connected to the SMA connector at the RF PORT. No DC offset voltage should be applied to the RF PORT.
- The amplitude of the applied signal should be adjusted to optimize the output signal.

Analog Modulators: Electrical Connections

- No voltage to the BIAS PORT is required in most applications.
- In some applications a bias voltage may be used to tune the operating point and minimize even order distortion products in the optical output signal.
- No DC offset voltage should be applied to the RF PORT.
- A DC voltage applied to the BIAS PORT may induce drift in the operating point over time. A customer-supplied bias control loop may be required to stabilize the operating point of the modulator if a DC voltage is applied to the BIAS PORT.
  If a zero volt operating point different than half intensity is required in an application, it can specified when a modulator is ordered.

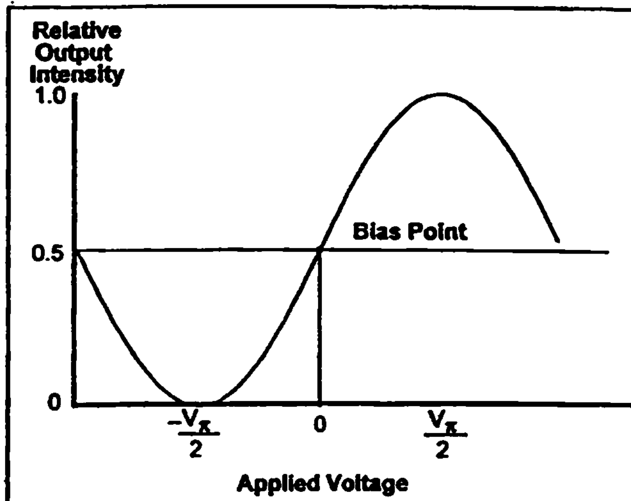


Fig 2. Modulator Transfer Function. The bias point is set during the manufacturing process to half intensity at zero volts.

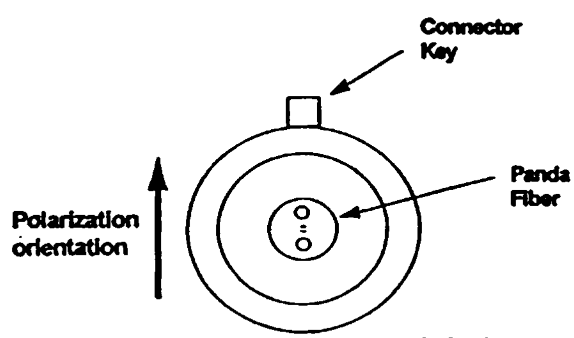


Figure 3: Standard fiber orientation for polarization maintaining fiber

UTP

For further information, request a copy of our UTP Designer's Guide to External modulation, or call us at (860) 769-3000 and ask for technical assistance on modulators, or fax us at (860) 769-3001.

CQF938/50

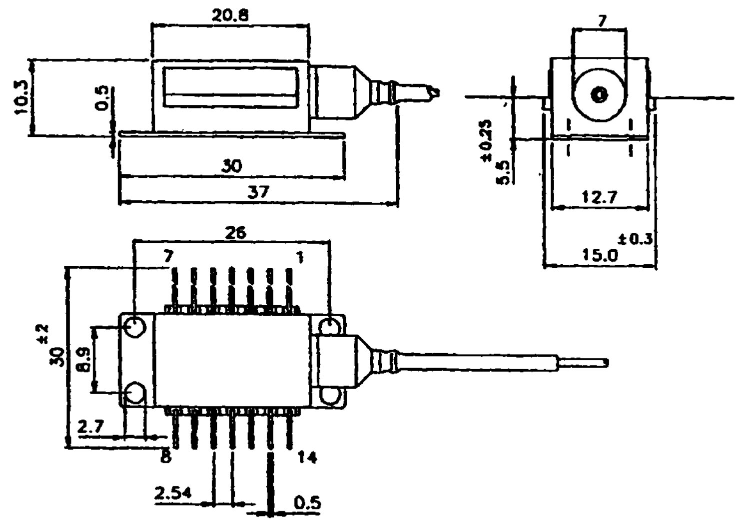
High power 1550 nm DFB laser with PMF fiber

FEATURES

- 1550 nm DFB laser diode
- 50 mW output power
- 25Ω electrical matching
- polarization maintaining fiber
- built-in thermo-electric cooler
- built-in optical isolator

MECHANICAL DATA

Dimensions in mm



Pinning

1 thermistor
2 thermistor
3 LD cathode DC input
4 PD anode
5 PD cathode
6 cooler anode
7 cooler cathode
8 case GND
9 case GND
10 not connected
11 LD anode, case
12 LD cathode, AC input
13 LD anode, case
14 not connected

CHARACTERISTICS (R_{th} = 10 kΩ, T_{case} = 25°C, P_0 = 50 mW unless otherwise specified)

Symbol	Parameter	Min	Typ	Max	Unit
I_{th}	threshold current	-	25	-	mA
P_0	output power from pigtail	50	-	-	mW
λ_c	central wavelength	-	1555	-	nm
SMSR	side mode suppression ratio	-	35	-	dB
RIN	relative intensity noise	-	-	-160	dB/Hz
$\Delta\lambda$	linewidth			1	MHz

Uniphase Netherlands B.V.
Ordering information: 9922 155 56014

Tentative Specification | **CQF938/50** | 9922 155 56014 | January 1999

LIMITING VALUES

Symbol	Parameter	Conditions	Min	Max	Unit
Laser diode					
P_0	radiant output power from pigtail		-	100	mW
V_R	reverse voltage		-	2.0	V
I_F	forward current		-	600	mA
Monitor diode					
V_R	reverse voltage		-	20	V
I_F	forward current		-	10	mA
Module					
T_{op}	operating temperature range	cooler active	-20	+70	°C
T_{stg}	storage temperature range		-40	+70	°C
Fibre pigtail					
R	bending radius		35	-	mm
F	tensile strength fibre to case		-	5	N

CHARACTERISTICS (R_{th} = 10 kΩ, T_{case} = 25°C, P_0 = 50 mW unless otherwise specified)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Laser diode						
P_0	radiant output power from pigtail		50	-	-	mW
I_{op}	operating current		-	475	500	mA
η	differential efficiency	see note 1	-	150	-	mW/A
I_{th}	threshold current		-	25	40	mA
V_F	forward voltage		-	-	5	V
λ_c	central wavelength		1547	1555	1560	nm
$\Delta\lambda$	linewidth		-	-	1	MHz
SMSR	side mode suppression ratio		30	35	-	dB
ISO	optical isolation		30	35	-	dB
RIN	relative intensity noise	20-1000MHz	-	-	-160	dB/Hz
Monitor diode (V_R = 10 V)						
R	monitor diode responsivity		3	50	-	mA/W
I_{md}	dark current		-	-	100	nA
TE	temperature tracking error	see note 2	-	-	15	%
Thermistor						
R_{th}	resistance	T_{th} = 25 °C	9.5	10	10.5	kΩ
ΔR/ΔT	response		-	-4	-	%/K
Thermo-electric cooler (ΔT = 40 °C)						
I_{cool}	cooler current		-	-	1.5	A
V_{cool}	cooler voltage		-	-	4.0	V
Polarization maintaining fiber pigtail						
l	length of pigtail		-	1	-	m
E.R.	extinction ratio		18	20	-	dB

Notes

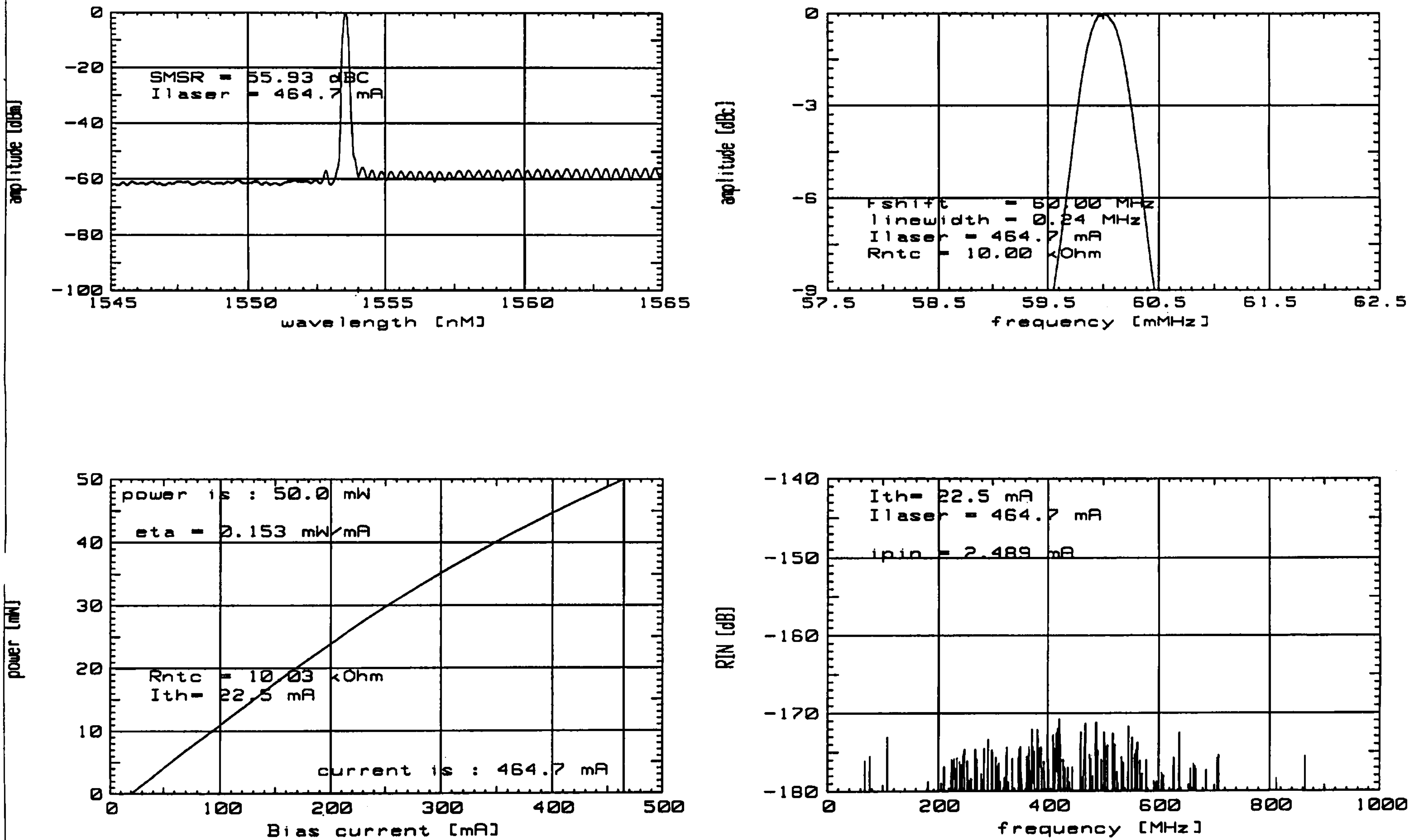
1. Differential efficiency is defined as increase in optical power divided by increase in diode current, beginning at the threshold current

$$\eta = \frac{P_0(I_L) - P_0(I_{th})}{I_L - I_{th}}$$

2. Tracking error is defined as the deviation of output power due to changes in case temperature over the maximum specified temperature range while the current of the monitor diode and the resistance of the thermistor are kept constant. Reference point is P_0 = 10 mW, R_{th} = 10.0 kΩ and T_{case} = 25 °C. The cooler current has to be controlled in such a way that the thermistor resistance remains constant at 10.0 kΩ.

$$TE = \frac{P_0(T_{case}) - P_0(25)}{P_0(25)} \times 100\%$$

CQF938/50 # 2424



PHILIPS OPTOELECTRONICS

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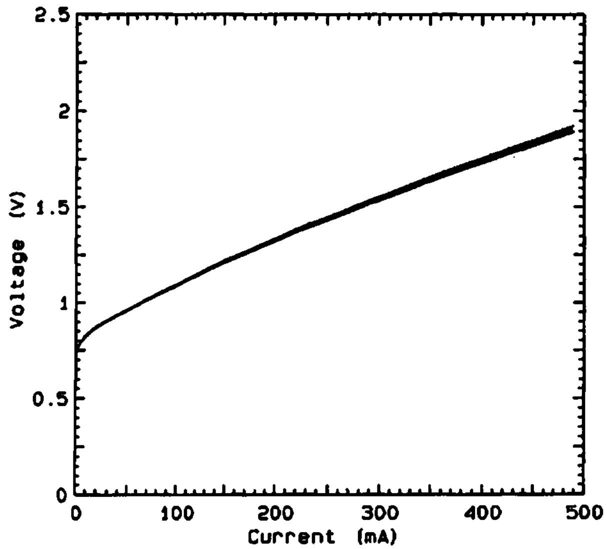
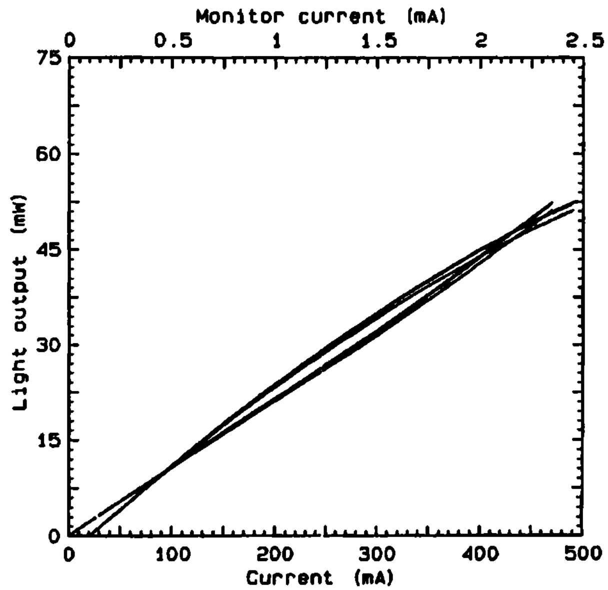
TEST DATA SHEET
CQF938/50 #2424

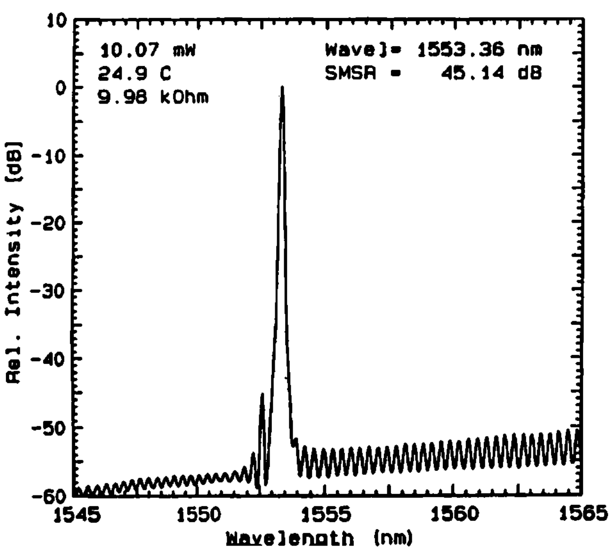
1550nm GaInAsP DFB-laserdiode with PM fibre pigtail





Temp	(C)	-15	25	65
Ith	(mA)	22.5	22.3	22.4
Ec	(mW/A)	129.7	129.1	126.1
Rs	(Ohm)	2.6	2.7	2.7
V30mA	(V)	0.91	0.91	0.91
Msens	(uA/mW)	45	45	46
V*	(V)	1.92	1.93	1.94
Mcur*	(uA)	2378	2378	2380
Rntc*	(kOhm)	9.99	9.97	9.98
Ipelt*	(mA)	199	-310	-1006
T.E.*	(%)	0.4	0.0	-1.8

*: at 500 mA



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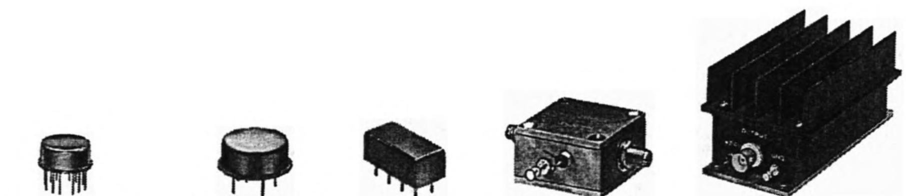

AMP-case QQ96 | AMP-case PP120 | MAN | ZFL-case Y39/460 | ZHL-1HLD

VARIABLE GAIN 10 to 1200 MHz

up to 20 mW (+13 dBm) output

MODEL NO.	FREQ. MHz f_L f_U	GAIN, dB Min.	Flatness Max.	Control range	MAXIMUM POWER, dBm Output (1 dB Comp.)	Input (no damage)	DYNAMIC RANGE NF dB Typ.	IP3 dBm Typ.	VSWR In	Out	DC POWER Volt V.	Current (mA)	CAPD DATA (see RF/IF Designer Handbook) Page	Case Style Note B	CONNECTION	Price $ Qty (1-9)
ZFL-1000GH *	10-1200	24	±1.5	30**	+13	+10	15	+25	2.2:1	2:1	15	170	3-33	Y39	-	219.00
ZFL-1000G *	10-1000	17	±1.5	30**	+3	+10	12	+13	2:1	2:1	15	100	3-33	Y39	-	199.00

* ZFL-1000GH and ZFL-1000G, all specifications at 0 Volts control voltage.
** Response time (10% to 90%) 25μsec., control voltage 0 to 5 volts.

HIGH ISOLATION 2 to 2000 MHz

up to 500 mW (+27 dBm) output

MODEL NO.	FREQ. MHz f_L f_U	GAIN, dB Min.	Flatness Max. m	Total Range	MAX. POWER, dBm Output (1 dB Comp.) L_w	U	Input (no damage)	DYNAMIC RANGE NF dB Typ.	IP3 dBm Typ.	VSWR (Typ.) In	Out	ACTIVE DIRECTIVITY* dB L_w Typ.	L_w Min.	U Typ.	U Min.	DC POWER Volt V.	Current (mA)	CAPD DATA (see RF/IF Designer Handbook) Page	Case Style Note B	CONNECTION	Price $ Qty (1-9)
MAN-1AD	5-500	16	±0.5	±1.0	+7	+6	+15	7.2	+20	1.6:1	1.7:1	35	25	30	20	12	85	3-34	A05	cc	26.45
MAN-11AD	2-2000	8	±0.5	±1.5	-2	-3.5(α)	+10	6.5	+14	3.0:1	2.0:1	21	14	16	12	15	22	3-34	A06	cc	31.95
MAN-2AD	2-1000	9	±0.4	±0.7	-2	-3.5	+10	6.5	+14	2.0:1	2.0:1	24	19	19	14	15	22	3-34	A06	cc	23.95
ZFL-11AD	2-2000	8	±0.5	±1.3	-2	-3.5(α)	+10	6.5	+14	2.5:1	2.0:1	21	14	16	12	15	22	3-34	Y39	-	91.95
ZFL-2AD	2-1000	9	±0.4	±0.5	-2	-3.5	+10	6.5	+14	2.0:1	2.0:1	24	19	19	14	15	22	3-34	Y39	-	83.95
ZFL-1HAD**	10-500	10	—	±1.0	+20	+20	+17	7.5	+30	1.3:1	1.35:1	30	20	25	18	15	115	3-35	SS98	-	210.00
ZFL-2HAD	50-1000	11	±0.7	±1.0	+20	+20	+15	5.0	+33	2.0:1	2.0:1	30	20	21	15	15	110	3-49	SS98	-	264.95
△ ZHL-1HLD	225-400	23	—	±1.0	+27	+27	+10	2.5	+40	2.0:1	2.0:1	34	28	34	28	24	525	3-35	T34	-	395.00

L_w = low range (f_L to $f_U/2$) m = mid range ($2f_L$ to $f_U/2$) U = upper range ($f_U/2$ to f_U)

* Active Directivity (dB) = Isolation (dB) - Gain (dB)
** Input VSWR of ZFL-1HAD in 10-20 MHz band increases to 1.45:1 at -55 deg.C. Below 50 MHz, NF increases to 11 dB typ at 10 MHz.
(α) Above 1 GHz, -5 dBm min.

NOTES:

✤ Max. voltage Vdc
▲ Available only with BNC connectors
△ Available only with SMA connectors
▼ SMA standard: Also available with BNC or type N connectors, please consult factory.
B. Connector types and case mounted options, case finishes are given in section 0, see "Case styles & outline drawings".
C. Prices and specifications subject to change without notice.
D. For Quality Control Procedures see Table of Contents, Section 0, "Mini-Circuits Guarantees Quality" article. For Environmental Specifications see Amplifier Selection Guide.
1. Absolute maximum power, voltage and current rating:
   - 1a. AMP models, 17V DC
   - 1b. MAN models, 12.5V DC
   - 1c. ZHL models, 28V DC (except ZHL-1HAD, 17V DC)
   - 1d. ZFL models, 17V DC (except ZFL-AD, 16V DC)
   - 1e. ZJL, ZKL models, 13V DC
2. With no load output, derate maximum input power (no damage) by 10 dB.

NSN GUIDE

MCL NO.	NSN
ZFL-1000H	5996-01-299-5588
ZFL-1000VH	5996-01-454-6938
ZFL-2000	5996-01-220-2213
ZFL-2000B	5996-01-220-2213
ZHL-6A	5996-01-330-3533

pin connections

PORT	cc	cd	ce
RF IN	1	2	5
RF OUT	8	4	11
DC	5	1	2
CASE GND	2,3,4,6	3	1,3,4,6,7 8,9,10,12
NOT USED	7	—	—

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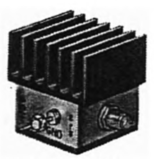
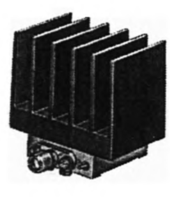
50 Ω

ZJL

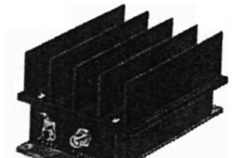
ZKL



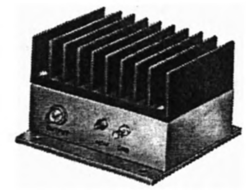
ZFL-case SS98



ZRON



ZHL-A



ZHL-1042J

LOW POWER 50 kHz to 7000 MHz

up to 16 mW (+12 dBm) output

MODEL NO.	FREQ. MHz f_L – f_U	GAIN, dB Typ.	GAIN, dB Min.	Flatness Typ.(1)	Flatness Max.	MAXIMUM POWER, dBm Output (1 dB Comp.) L_w	Output (1 dB Comp.) U	Input (no damage)	DYNAMIC RANGE(1) NF dB Typ.	IP3 dBm Typ.	VSWR (Typ.) In	VSWR (Typ.) Out	DC POWER Volt V.	DC POWER Current (mA)	CAPD DATA (see RF/IF Designer Handbook) Page	Case Style Note B	CONNECTION	Price $ Qty (1-9)
ZJL-7G	20-7000	10	7.5	±1.0	—	+8	+9	+15	5.0	+24	1.5:1	1.5:1	12	50	3-50	BW459	-	99.95
ZJL-6G	20-6000	13	10	±1.6	—	+9	+10	+15	4.5	+24	1.5:1	1.4:1	12	50	3-50	BW459	-	114.95
ZJL-3G	20-3000	19	14	±2.2	—	+8	+8	+13	3.8	+22	1.4:1	1.6:1	12	45	3-51	BW459	-	114.95
▼ ZFL-500	0.05-500	—	20	—	±1.0	—	+9	+5	5.3	+18	1.9:1	1.9:1	15	80	3-37	Y460	-	69.95
ZFL-750	0.2-750	—	18	—	±0.5	—	+9 ***	+5	6.0	+18	1.5:1	2:1	15	90	3-37	Y460	-	74.95
ZFL-1000	0.1-1000	—	17	—	±0.6	—	+9 *	+5	6.0	+18	1.5:1	2:1*	15	105	3-37	Y460	-	79.95
AMP-3G	30-3000	—	8	—	±0.75	+9.5	+9.5	+13	3.5**	+20	2.6:1	2.5:1	15	55	3-38	PP120	cd	89.95
AMP-74	5-500	—	27	—	±1.0	+7.0	+7.0	+13	5.0	+20	2:1	2:1	15	44	3-36	PP120	cd	54.95
MAN-1	0.5-500	—	28	—	±1.4	+8	+8	+15	4.5	+18	1.8:1	1.8:1	12	60	3-36	A05	cc	15.95
MAN-2	0.5-1000	—	18	—	±1.5	+9	+7	+15	6.0	+19	1.8:1	1.8:1	12	85	3-36	A05	cc	19.95

L_w = low range (f_L to $f_U/2$) U = upper range ($f_U/2$ to f_U)

*ZFL-1000 output VSWR 2.8:1 maximum over 750-1000 MHz; 1 dB compression +7 dBm at 500-1000 MHz ***+7 dBm from 500 to 750 MHz.
**NF increases with decreasing frequency, 5 dB typical at 300 MHz, and 10 dB typical at 30 MHz. (1)ZJL models: Flatness specified to 0.75 f_U, dynamic range at 2 GHz.

MEDIUM POWER 2.5 kHz to 8000 MHz

up to 320 mW (+25 dBm) output

MODEL NO.	FREQ. MHz f_L – f_U	GAIN, dB Typ.	GAIN, dB Min.	Flatness Typ.(1)	Flatness Max.	MAXIMUM POWER, dBm Output (1 dB Comp.) L_w	Output (1 dB Comp.) U	Input (no damage)	DYNAMIC RANGE(1) NF dB Typ.	IP3 dBm Typ.	VSWR (Typ.) In	VSWR (Typ.) Out	DC POWER Volt V.+	DC POWER Current (mA)	CAPD DATA (see RF/IF Designer Handbook) Page	Case Style Note B	CONNECTION	Price $ Qty (1-9)
AMP-2000	10-2000	—	20	—	±1.5	+15		+5	5	+25	2:1	2:1	15	100	3-38	QQ96	ce	139.95
ZFL-2000	10-2000	—	20	—	±1.5	+16*		+5	7	+25	2:1	2:1	15	120	3-40	Y39	-	219.00
ZFL-2500	500-2500	—	28	—	±1.5	+15		+5	8	+27	2.5:1	2.5:1	5	220	3-54	Y460	-	99.95
→ ZFL-2500VH	10-2500	—	20	—	±1.5	+23		+10	5.5	+35	1.7:1•	2:1•	15	300	3-54	SS98	-	264.95
ZFL-1000H	10-1000	—	28	—	±1.0	+20		+5	5	+33	2:1	2:1	15	160	3-39	SS98	-	219.00
ZFL-1000VH	10-1000	—	20	—	±1.0	+25		+15	4.5	+38	2:1**	2.5:1	15	320	3-39	SS98	-	229.00
NEW ZFL-1000VH2	10-1000	28	26	—	±1.0	+25		+15	5.0	+38	2:1	2.5:1	15	320	3-39	SS98	-	249.00
ZRON-8G	2000-8000	—	20	—	±1.5★	+20		+10	6	+30	2:1	2:1	15	310	3-55	AV243	-	495.00
▲ ZHL-6A	.0025-500	—	21		±1.2	+22		+10	7.5***	+34	1.8:1	2:1***	24	350	3-41	S32	-	199.00
ZHL-1042J	10-4200	—	25	—	±1.5	+20		+10	6	+30	2.5:1	2.5:1	15	330	3-40	NN92	-	495.00
ZJL-4G	20-4000	12.4	10.0	±0.25	—	+13.5	+11	+20	5.5	+30.5	1.4:1	1.6:1	12	75	3-51	BW459	-	129.95
ZJL-4HG	20-4000	17.0	13.0	±1.5	—	+15.0	+12	+13	4.5	+30.5	1.5:1	1.4:1	12	75	3-49	BW459	-	129.95
ZJL-5G	20-5000	9.0	7.0	±0.55	—	+15.0	+9.5	+20	8.5	+32	1.6:1	1.3:1	12	80	—	BW459	-	129.95
ZKL-2R7	10-2700	24.0	20.0	—	±0.7	+13	+13	+13	5.0	+30	1.3:1	1.4:1	12	120	3-53	BY493	-	149.95
ZKL-2R5	10-2500	30.0	26.0	—	±1.5	+15	+15	+13	5.0	+31	1.4:1	1.4:1	12	120	3-53	BY493	-	149.95
→ ZKL-2	10-2000	33.5	30.0	—	±1.0	+15	+15	+13	4.0	+31	1.4:1	1.4:1	12	120	3-52	BY493	-	149.95
ZKL-1R5	10-1500	40.0	36.0	—	±1.2	+15	+15	+13	3.0	+31	1.4:1	1.6:1	12	115	3-52	BY493	-	149.95

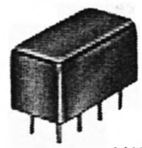
L_w = low range (f_L to $f_U/2$) U = upper range ($f_U/2$ to f_U)

- * +15 dBm below 1000 MHz
- ** Input VSWR 2:1 max, increasing below 20 MHz to 2.25:1 max at 10 MHz.
- *** NF specified above 10 MHz and output VSWR 2.8:1 below 30 MHz
- • Max. VSWR In 2.0:1, Out 2.5:1
- ★ Measured at 25°C.
- (1) ZJL models: Flatness specified to 0.75 f_U, dynamic range at 2 GHz.

Low-Noise Amplifiers 50Ω

Broadband, Linear 0.1 to 2400 MHz

AMP



MAN

ZFL

TO

up to +16 dBm output

MODEL NO.	FREQ. MHz f_L f_U	NF dB Typ.	GAIN, dB Min.	Flatness m	Max.	MAXIMUM POWER, dBm Output (1 dB Comp.)	Input (no damage)	INTERCEPT POINT, dBm IP3 Typ.	VSWR Typ. In	Out	DC POWER Volt V.	Current (mA)	CAPD DATA (see RF/IF Designer Handbook) Page	CASE STYLE Note B	CONNECTION	Price $ Qty (1-9)
AMP-11-2	5-1000	3	14	±1.0	±1.0	-3.5	+13	+13	2:1	2:1	15	12	3-27	PP120	cd	44.95
AMP-15	5-1000	2.8	13	±0.6	±1.2	+8	+13	+22	2:1	2:1	15	29	3-27	PP120	cd	49.95
AMP-75	5-500	2.4	19	±0.4	±1.0	+12	+13	+28	2:1	2:1	15	29	3-27	PP120	cd	49.95
AMP-76	5-500	3.1	26	±0.7	±1.0	+13.5	+6	+28	2:1	2:1	15	68	3-35	PP120	cd	78.95
AMP-77	5-500	3.3	15	±0.4	±1.0	+16	+13	+32	2:1	2:1	15	56	3-28	PP120	cd	55.95
MAN-1LN**	0.5-500	3.0	28	±0.5	±1.4	+7	+15	+18	1.8:1	1.8:1	12	60	3-28	A05	cc	19.95
MAN-1HLN	10-500	3.7	10	±0.5	±0.8	+15	+15	+30	1.8:1	1.8:1	12	70	3-28	A06	cc	19.95
ZFL-500HLN	10-500	3.8	19	—	±0.4	+16	+15	+30	2:1	2:1	15	110	3-29	Y460	-	99.95
ZFL-500LN*	0.1-500	2.9	24	—	±0.5	+5	+5	+14	1.5:1	1.6:1	15	60	3-29	Y460	-	79.95
ZFL-1000LN	0.1-1000	2.9	20	—	±0.5	+3	+5	+14	1.5:1	2:1	15	60	3-29	Y460	-	89.95

m = mid range (2 f_L to f_U/2)

features

- ideal for printed-circuit designs (MAN & AMP series)
- smooth response over entire band, no external resonances
- low impedance, less susceptible to EMI
- easy to use, 50 ohm input/output
- all models are cascadable

NOTES:

* VSWR 1.6:1 maximum from 0.1 to 0.2 MHz. Also available with BNC connectors.
** Below 5 MHz, 1 dB compression point decreases to 6.5 dBm.
Δ Available only with SMA connectors
B. Connector types and case mounted options, case finishes are given in section 0, see "Case styles & outline drawings".
C. Prices and specifications subject to change without notice.
D. For Quality Control Procedures see Table of Contents, Section 0, "Mini-Circuits Guarantees Quality" article. For Environmental Specifications see Amplifier Selection Guide.
1. Absolute maximum power, voltage and current rating:
   1a. AMP models, 17V DC.
   1b. MAN models, 12.5V DC.
2. With no load at output, derates maximum input power (no damage) by 10 dB.
3. ZFL and TO models, NF specified at room temperature, increases to 2 dB typical at +85 deg.C.
4. ZHL models, NF specified at room temperature, increases to 2.3 dB maximum at +65 deg.C.

NSN GUIDE

MCL NO.	NSN
AMP-15	5895-01-350-9550
AMP-75	5895-01-350-9551
AMP-77	5895-01-350-9549
ZFL-1000LN	5996-01-412-3031

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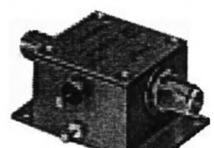
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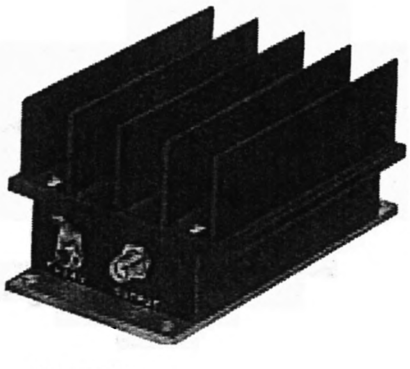
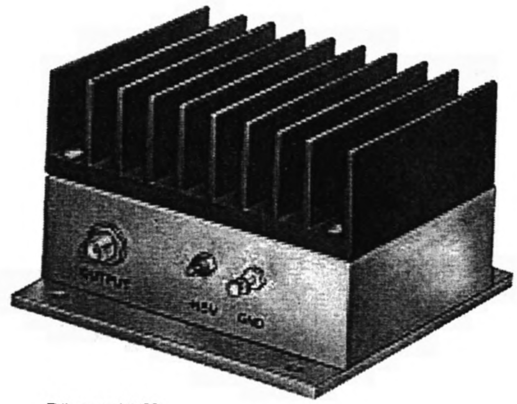

ZHL-case S32



ZHL-case NN92

up to +26 dBm output

MODEL NO.	FREQ. MHz f_L f_U	NF dB Max.	GAIN, dB Min.	GAIN, dB Flatness Max.	MAXIMUM POWER, dBm Output (1 dB Comp.) Min.	MAXIMUM POWER, dBm Input (no damage)	INTERCEPT POINT, dBm IP3 Typ.	VSWR Max. In	VSWR Max. Out	DC POWER Volt V.	DC POWER Current (mA)	CAPD DATA (see RF/IF Designer Handbook) Page	CASE STYLE Note B	CONNECTION	Price $ Qty (1-9)
TO-0812LN	800-1200	1.6	20	±1.0	+8	+13	+18	2.5:1	2.5:1	15	70	3-30	QQ96	ce	199.00
TO-1217LN	1200-1700	1.6	20	±1.0	+10	+13	+25	2.5:1	2.5:1	15	70	3-30	QQ96	ce	199.00
TO-1724LN	1700-2400	1.6	20	±1.0	+10	+13	+22	2.5:1	2.5:1	15	70	3-30	QQ96	ce	199.00
△ ZEL-0812LN	800-1200	1.5	20	±1.0	+8	+13	+18	2.5:1	2.5:1	15	70	3-31	EEE132	-	274.95
→ △ ZEL-1217LN	1200-1700	1.5	20	±1.0	+10	+13	+25	2.5:1	2.5:1	15	70	3-31	EEE132	-	274.95
△ ZEL-1724LN	1700-2400	1.5	20	±1.0	+10	+13	+22	2.5:1	2.5:1	15	70	3-31	EEE132	-	274.95
NEW △ ZHL-0812MLN	800-1200	1.6	28	±1.0	+20	0	+33	2.5:1	2.5:1	15	300	—	S32	-	295.00
NEW △ ZHL-1217MLN	1200-1700	1.5	30	±1.0	+20	0	+34	2.5:1	2.5:1	15	300	—	S32	-	295.00
NEW △ ZHL-1724MLN	1700-2400	1.5	28	±1.0	+20	0	+32	2.5:1	2.5:1	15	300	—	S32	-	295.00
△ ZHL-0812HLN	800-1200	1.5	30	±1.0	+26	+10	+36	2.4:1	2.4:1	15	725	3-32	NN92	-	399.50
△ ZHL-1217HLN	1200-1700	1.5	30	±1.0	+26	+10	+36	2.4:1	2.4:1	15	725	3-32	NN92	-	399.50
△ ZHL-1724HLN	1700-2400	1.5	30	±1.0	+26	+10	+36	2.4:1	2.4:1	15	725	3-32	NN92	-	399.50

features

- very low noise
- high dynamic range (ZHL-HLN series)
- ideal for printed-circuit designs (TO series)
- smooth response over entire band, no external resonance
- easy to use, 50 ohms input/output
- all models are cascadable

pin connections

PORT	cc	cd	ce
RF IN	1	2	5
RF OUT	8	4	11
DC	5	1	2
CASE GND	2,3,4,6	3	1,3,4,6,7,8,9,10,12
NOT USED	7	—	—

990614

Tentative Specification **9922 158 ###14 January 1999**

CQF915/28## - New Digital laser

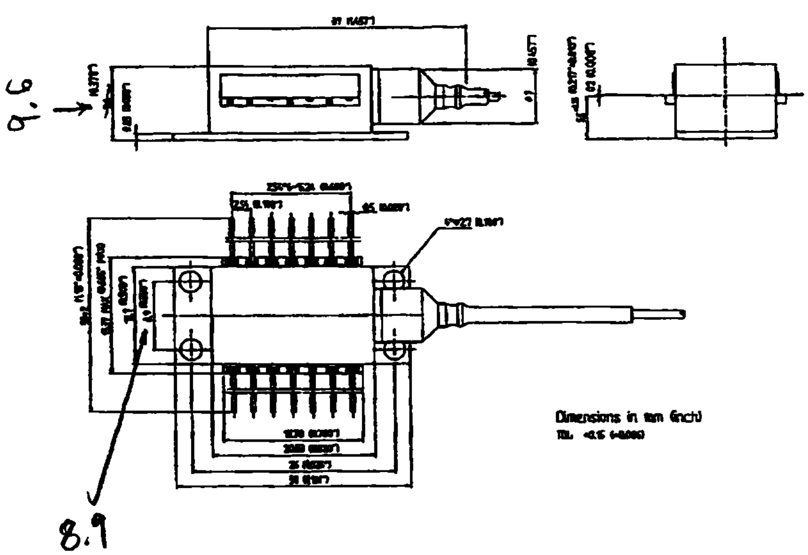
1550nm Directly Modulated DFB laser for WDM telecom

FEATURES

- 1550 nm DFB laser diode
- 2.5 Gbit/s
- 25Ω electrical matching
- dispersion 1800 ps/nm
- internal bias-T network
- built-in thermo-electric cooler
- built-in optical isolator
- 0.8 nm (100 GHz) spacing
- 0.4 nm (50 GHz) spacing optional

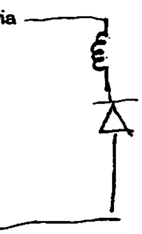
MECHANICAL DATA

Dimensions in mm



Pinning

1 thermistor
2 thermistor
3 LD cathode DC input via inductance
4 PD anode
5 PD cathode
+ 6 cooler anode
– 7 cooler cathode
8 case GND
9 case GND
10 not connected
11 LD anode, case
12 LD cathode, AC input
13 LD anode, case
14 not connected



CHARACTERISTICS (R_{th}= 10 kΩ)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
I_{th}	threshold current		-	25	35	mA
P_0	output power from pigtail		-	5	-	mW
η	differential efficiency	P_0 = 5 mW	100	-	200	mW/A
λ_c	central wavelength		1530	-	1560	nm
λ_{set}	Laser set temperature for λ_c		25	-	35	°C
SMSR	side mode suppression ratio	P_0 = 5 mW	30	35	-	dB
B_{-3dB}	bandwidth (-3dB)		3	-	-	GHz

$V = IR$ $I = \frac{0.720}{10} = 72$ mA

Uniphase Netherlands B.V.
Ordering information: 9922 158 ###14

LIMITING VALUES

Symbol	Parameter	Conditions	Min	Max	Unit
Laser diode					
P_0	radiant output power from pigtail		-	15	mW
V_R	reverse voltage		-	2.0	V
I_F	forward current		-	200	mA
Monitor diode					
V_R	reverse voltage		-	20	V
I_F	forward current		-	10	mA
Module					
T_{op}	operating temperature range	cooler active	-5	+70	°C
T_{stg}	storage temperature range		-40	+85	°C
Fibre pigtail					
R	bending radius		35	-	mm
F	tensile strength fibre to case		-	5	N

CHARACTERISTICS (R_{th} = 10 kΩ, P_0 = 5 mW unless otherwise specified)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Laser diode						
I_{op}	operating current		-	-	150	mA
η	differential efficiencysee note 1		100	-	200	mW/A
I_{th}	threshold current		-	25	35	mA
V_F	forward voltage		-	-	2.0	V
λ_c	central wavelength, see table 1		1530	-	1560	nm
T_λ	laser set temperature for λ_c		20	-	35	°C
SMSR	side mode suppression ratio		30	35	-	dB
t_r, t_f	rise, fall time		-	125	-	ps
DP	dispersion penalty at BER = 10^{-10}	1800 ps/nm, NRZ, ER ≤ 10 dB, PRBS = 2^{31}-1	-	-	1.5	dB
ISO	optical isolation		30	35	-	dB
RF characteristics						
S_{21}	bandwidth (-3dB)		3	-	-	GHz
S_{21}	In band ripple	from 3 MHz to 3 GHz			1.5	dB
S_{11}	Return loss	from 3 MHz to 2 GHz			-8	dB
S_{11}	Return loss	from 2 GHz to 3 GHz			-6.5	dB
Monitor diode (V_R = 10 V)						
R	monitor diode responsivity		25	-	500	mA/W
TE	temperature tracking errorsee note 2		-	-	10	%
Thermistor						
R_{th}	resistance	T_{th} = 25 °C	9.5	10	10.5	kΩ
Thermo-electric cooler (ΔT = 45 °C)						
I_{cool}	cooler current		-	-	1.2	A
V_{cool}	cooler voltage		-	-	2.5	V
Single mode fibre pigtail						
$Ø_{mf}$	mode field diameter		-	9.0	-	µm
$Ø_{cl}$	cladding diameter		123.5	125	126.5	µm
e	eccentricity of core		-	-	1.0	µm
t_{pc}	thickness of primary coating		-	60	-	µm
$Ø_{sc}$	diameter of polyamide secondary coating		-	950	-	µm
l	length of pigtail		-	2	-	m

Notes

1. Differential efficiency is defined as increase in optical power divided by increase in diode current, beginning at the threshold current

$$\eta = \frac{P_0(I_L) - P_0(I_{th})}{I_L - I_{th}}$$

2. Tracking error is defined as the deviation of output power due to changes in case temperature over the maximum specified temperature range while the current of the monitor diode and the resistance of the thermistor are kept constant. Reference point is P_0 = 5 mW, R_{th} = 10.0 kΩ and T_{case} = 25 °C. The cooler current has to be controlled in such a way that the thermistor resistance remains constant at 10.0 kΩ.

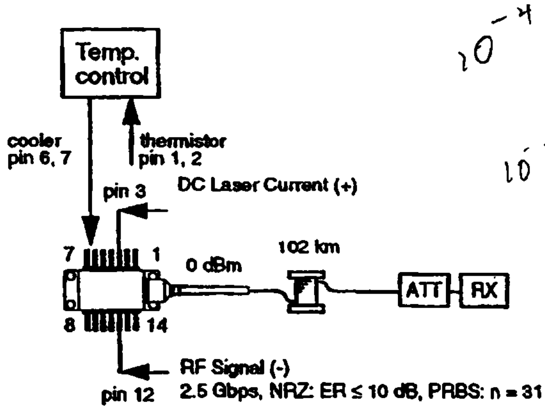
$$TE = \frac{P_0(T_{case}) - P_0(25)}{P_0(25)} \times 100\%$$

Tentative Specification 9922 158 ##14 January 1999

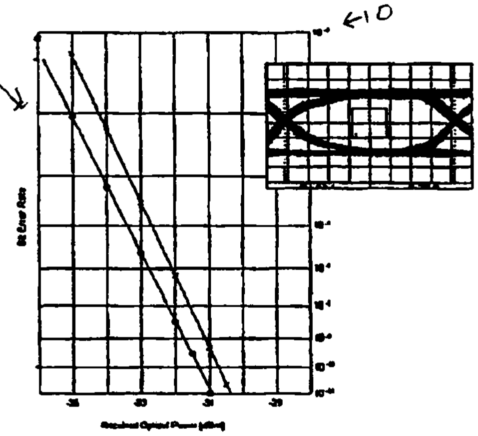
CQF915/28##

The CQF915 has been especially developed for use in WDM systems where it is used as a directly modulated wavelength selected source. The wavelengths that can be selected fully comply with the ITU recommendation for multichannel systems both in range (43 channels ranging from 1530.33 to 1563.86 nm) and in channel definition, adhering to the 100 GHz grid (0.8 nm) relative to a frequency of 193.1 THz (i.e. a wavelength of 1552.52 nm). An advanced logistic system has been adopted which allows optimum handling and planning of different wavelengths. This logistic system also enables customization of the wavelength spacing to a 50GHz grid (0.4nm). The wavelength of each laser is accurately measured and each laser is accompanied by a datasheet with the laser performance at the temperature T_λ where the required wavelength channel is reached. The laser chip relies on multi-quantum-well technology and a semi-insulating planar buried heterostructure, and shows excellent side-mode suppression ratios (typ. 45 dB) and small linewidths (<5 MHz). Long term wavelength drift experiments have been performed to warrant long-term wavelength stability. The 25 Ω butterfly packaged laser is pigtailed with a single mode fiber and shows excellent thermal stability (e.g. wavelength drift with case temperature is better than 0.001 nm/°C). The package also features a cooled isolator thereby reducing the dependence of the optical isolation on case temperature. The internal bias-T network and built-in monitor diode enables simple DC-bias conditioning and output power stabilization of the laser diode. Under small signal modulation conditions, the minimum bandwidth of the device exceeds 2.5GHz. Due to the intrinsic low chirp characteristic of the DFB laser, the device is especially suitable for digital transmission at 1550nm, based on standard single-mode fibre with non-zero dispersion, the maximum dispersion penalty at BER = 10^{-10} is e.g. less than 1.5 dB for a total dispersion of 1800ps/nm.

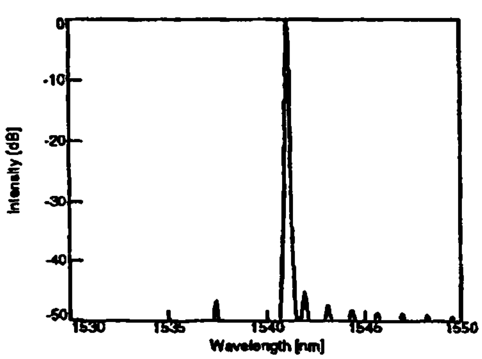
TYPICAL PERFORMANCE CHARACTERISTICS



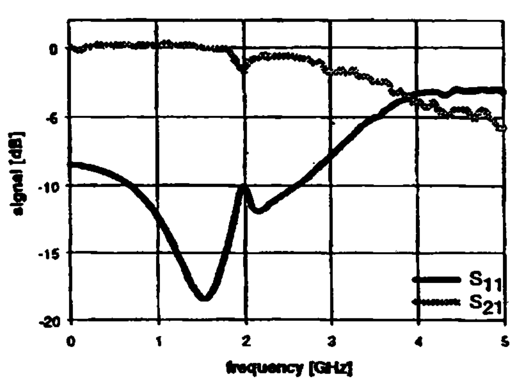
Each CQF915 laser is separately tested for dispersion penalty using a set-up with a total fiber length of 102 km (1800 ps/nm @ 18/ps/nm/km).



Typical Bit Error Rate measurement and eye-diagram (2.5 Gb/s, NRZ, ER ≤ 10dB, PRBS: n = 31). Dispersion Penalty DP is better than 1.5dB at BER = 10^{-10}.



The spectral behaviour measured at an output power of 5mW.



Typical RF behaviour measured at an average output power of 5mW.

Tentative Specification 9922 158 ##14 January 1999

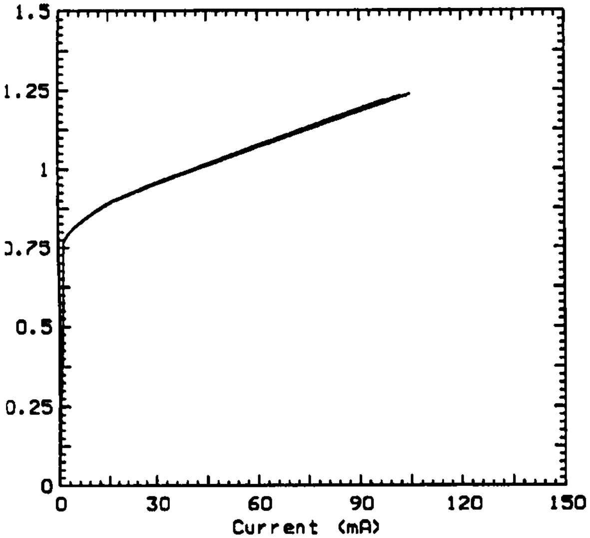
CQF915/28##

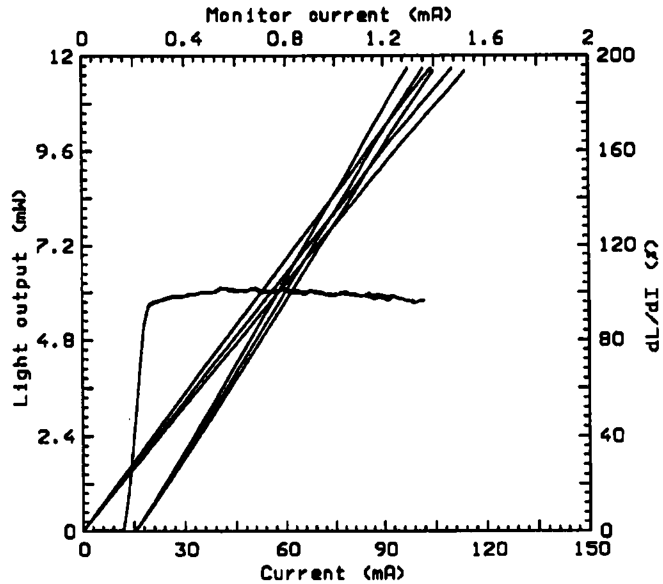
Table 1

central wavelength (vacuum) λ_c (nm)	optical frequency f_c (THz)	channel #	Typenr.	Ordering Code
1530.33	195.9	01	CQF915/2801	9922 158 53714
1531.12	195.8	02	CQF915/2802	9922 158 53814
1531.90	195.7	03	CQF915/2803	9922 158 53914
1532.68	195.6	04	CQF915/2804	9922 158 54014
1533.47	195.5	05	CQF915/2805	9922 158 54114
1534.25	195.4	06	CQF915/2806	9922 158 54214
1535.04	195.3	07	CQF915/2807	9922 158 54314
1535.82	195.2	08	CQF915/2808	9922 158 54414
1536.61	195.1	09	CQF915/2809	9922 158 54514
1537.40	195.0	10	CQF915/2810	9922 158 54614
1538.19	194.9	11	CQF915/2811	9922 158 54714
1538.98	194.8	12	CQF915/2812	9922 158 54814
1539.77	194.7	13	CQF915/2813	9922 158 54914
1540.56	194.6	14	CQF915/2814	9922 158 55014
1541.35	194.5	15	CQF915/2815	9922 158 55114
1542.14	194.4	16	CQF915/2816	9922 158 55214
1542.94	194.3	17	CQF915/2817	9922 158 55314
1543.73	194.2	18	CQF915/2818	9922 158 55414
1544.53	194.1	19	CQF915/2819	9922 158 55514
1545.32	194.0	20	CQF915/2820	9922 158 55614
1546.12	193.9	21	CQF915/2821	9922 158 55714
1546.92	193.8	22	CQF915/2822	9922 158 55814
1547.72	193.7	23	CQF915/2823	9922 158 55914
1548.51	193.6	24	CQF915/2824	9922 158 56014
1549.32	193.5	25	CQF915/2825	9922 158 56114
1550.12	193.4	26	CQF915/2826	9922 158 56214
1550.92	193.3	27	CQF915/2827	9922 158 56314
1551.72	193.2	28	CQF915/2828	9922 158 56414
1552.52	193.1	29	CQF915/2829	9922 158 56514
1553.33	193.0	30	CQF915/2830	9922 158 56614
1554.13	192.9	31	CQF915/2831	9922 158 56714
1554.94	192.8	32	CQF915/2832	9922 158 56814
1555.75	192.7	33	CQF915/2833	9922 158 56914
1556.55	192.6	34	CQF915/2834	9922 158 57014
1557.36	192.5	35	CQF915/2835	9922 158 57114
1558.17	192.4	36	CQF915/2836	9922 158 57214
1558.98	192.3	37	CQF915/2837	9922 158 57314
1559.79	192.2	38	CQF915/2838	9922 158 57414
1560.61	192.1	39	CQF915/2839	9922 158 57514
1561.42	192.0	40	CQF915/2840	9922 158 57614
1562.23	191.9	41	CQF915/2841	9922 158 57714
1563.05	191.8	42	CQF915/2842	9922 158 57814
1563.86	191.7	43	CQF915/2843	9922 158 57914

TEST DATA SHEET
CQF915/2801 #43274

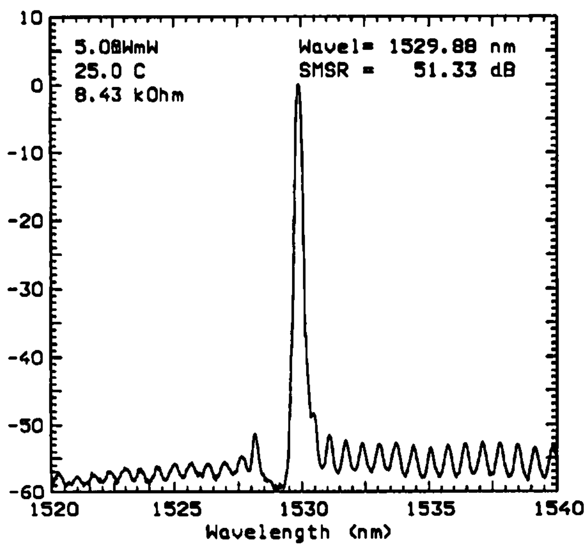
1550nm GaInAsP DFB-laserdiode with monomode fibre pigtail





Temp	(C)	0	25	65
Ith	(mA)	15.9	15.9	15.9
Ec	(mW/A)	131.4	136.7	143.7
Rs	(Ohm)	3.8	3.9	3.9
Iop*	(mA)	53.4	52.4	50.6
Rntc*	(kOhm)	8.45	8.46	8.46
Ipelt*	(mA)	310	16	-510
Imon*	(uA)	632	614	581
Vop*	(V)	1.04	1.04	1.04
Vpelt*	(V)	-0.59	-0.04	1.04
T.E.	(%)	-2.9	0.0	5.7
Wavel	(nm)		1530.32	
Top	(C)		29.3	
Rntc@25C	kOhm		9.88	
Date	(YYMMDD)		990906	

* : at P=5 mW



APPROVED BY :

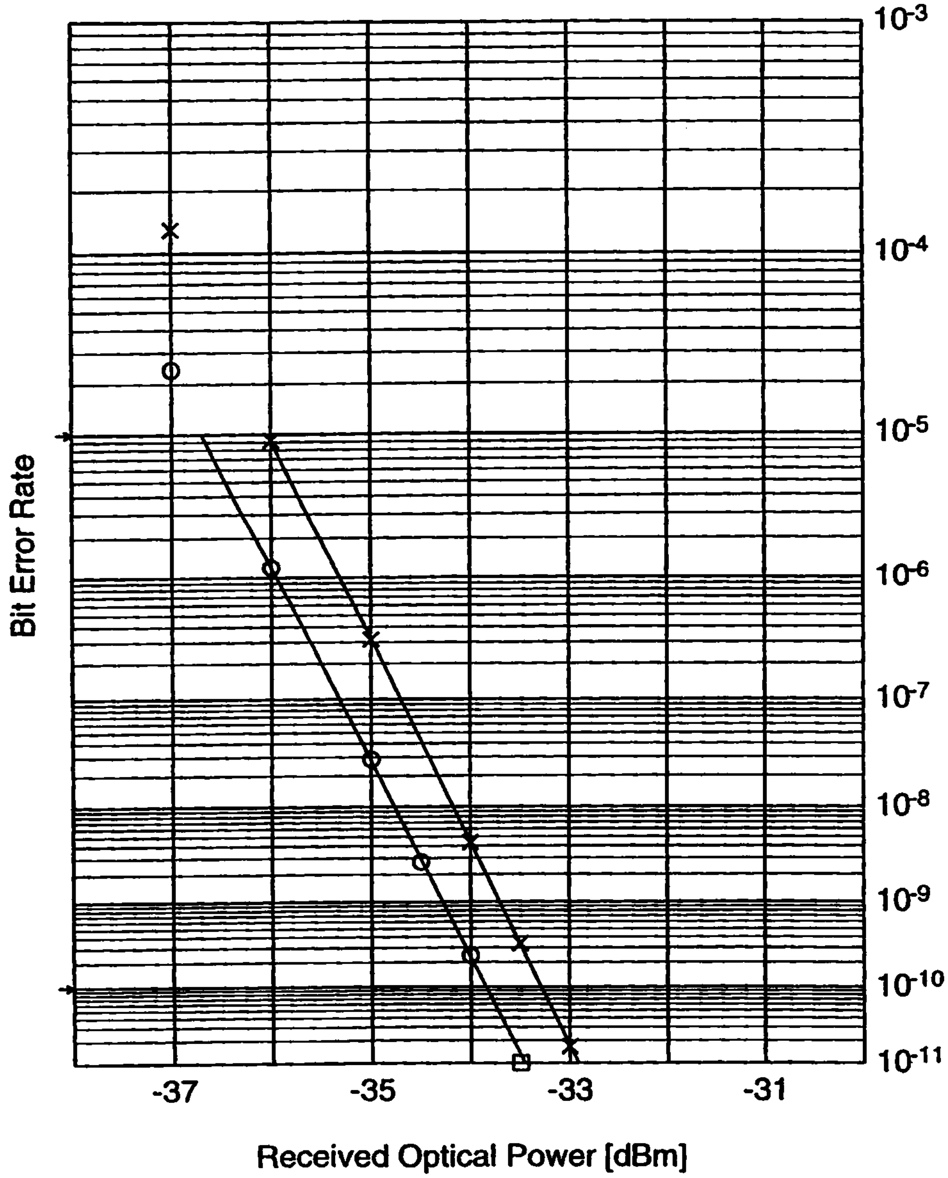
UNIPHASE NETHERLANDS B.V. 6 Sep 1999 9:03

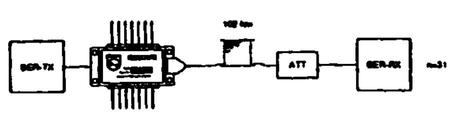
CQF915/2801 # 43274

Date: 30-08-1999
Time: 12:48:35

Power: (avg)	7.00	dBm	(I= 47.4 mA)
E.R.:	10.1	dB	(2.00 V)
Dispersion:	1800	ps/nm	(102 km @ 18 ps/nm/km)

DP:	0.56	dB	(n=31, BER=1.0E-10)
BB:	-33.85	dBm	

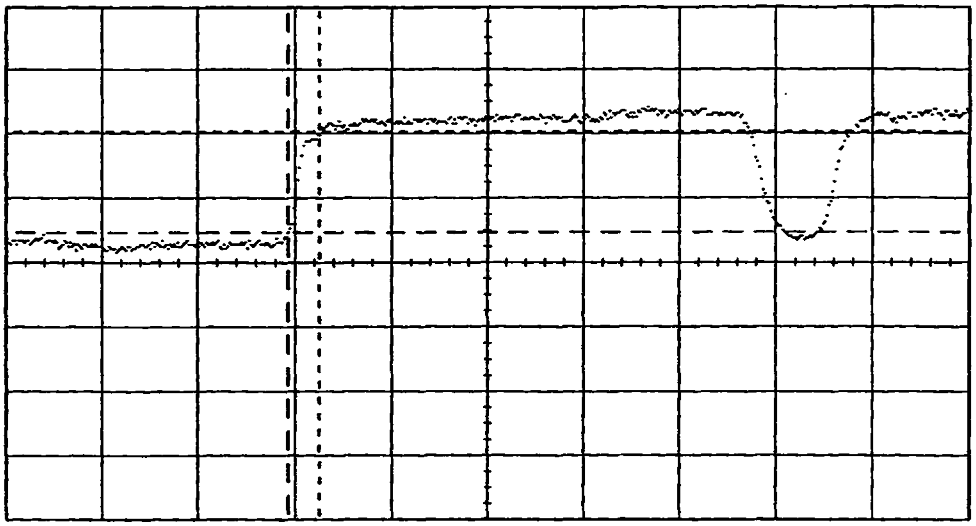


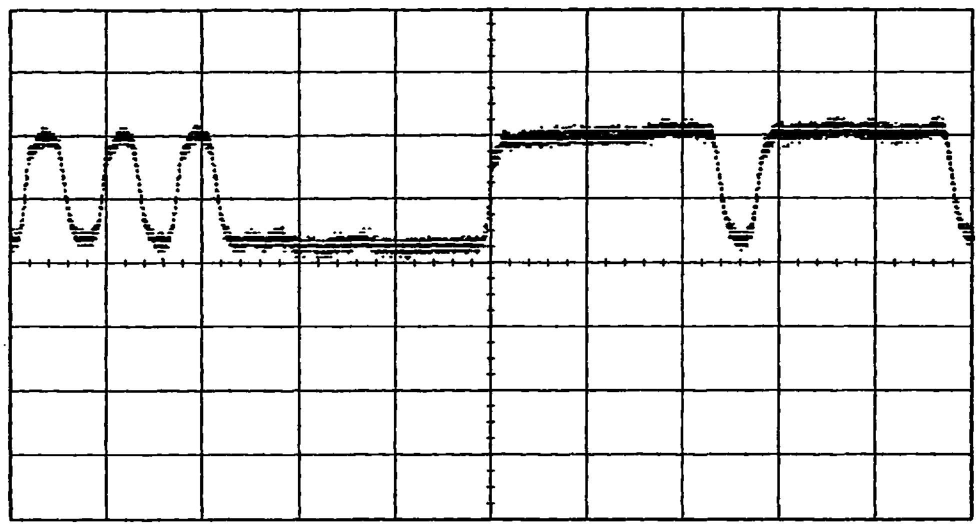


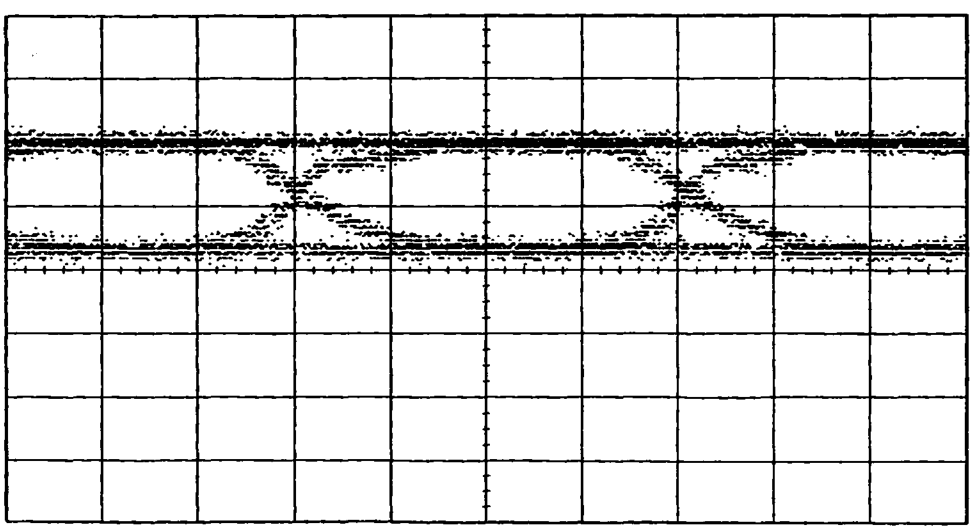
CQF915/2801 # 43274

Date: 30-08-1999
Time: 12:48:36

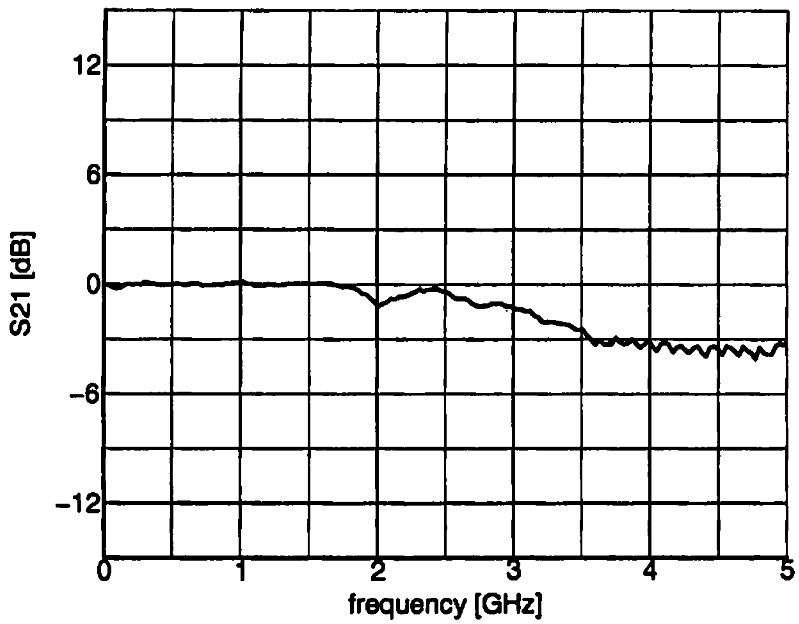
Power: (avg)	7.00	dBm	(I= 47.4 mA)
E.R.:	10.1	dB	(2.00 V)

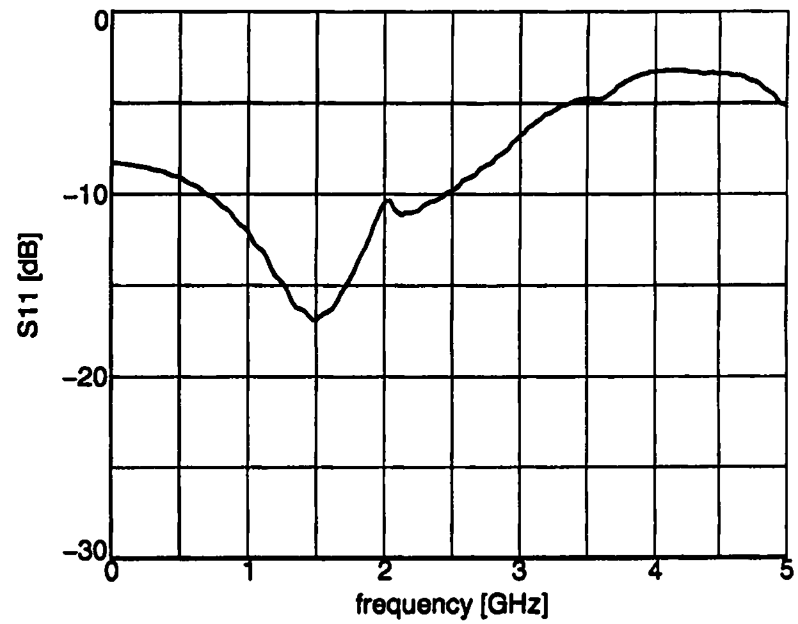






CQF915/2801 #43274





Pf 5.0 mW

Approved by :

Uniphase Netherlands B.V. 7 Sep 1999

Airpak
transmitter and receiver modules

Product changes
In seeking to provide greater value to our customers, Laser Diode, Inc. may make changes to its products that deviate from the information in this document.

Personal hazard
Normal aversion reactions will protect from radiation hazards to the eye associated with devices of this kind. Direct and prolonged exposure to a laser beam may cause eye damage. Observe precautions accompanying the product and precautions appropriate to a Class IIIb laser.

Handling precautions
Handle optical fiber with normal care, avoiding stretch, tension, twist, kink, or bend abuse. Products are subject to the risks normally associated with sensitive electronic devices including static discharge, transients, and overload.

Special orders
Some products can be supplied with performance characteristics that will meet special customer requirements and that are different from those indicated herein. Contact the Laser Diode Sales Department or your local Laser Diode representative to discuss your requirements.

Ordering
Products can be ordered directly from Laser Diode, Inc. or from its representatives. Refer to the following order numbers:

Transmitter ordering information

Part Number	Typical Rate (NRZ Mb/s)	Central Wavelength (nm)	Typical P_{AVG} (dBm)	Interface Type	Operating Temperature (°C)
TL 2063PT-010FC	155	1310	-8	9/125 pigtail, FC/PC connector	-40 to +85
TL 2063PT-005FC	155	1310	-3	9/125 pigtail, FC/PC connector	-40 to +85
TL 2065PT-010FC	155	1550	-8	9/125 pigtail, FC/PC connector	0 to +65
TL 2083PT-010FC	622	1310	-8	9/125 pigtail, FC/PC connector	-40 to +85
TL 2083PT-005FC	622	1310	-3	9/125 pigtail, FC/PC connector	-40 to +85
TL 2085PT-010FC	622	1550	-8	9/125 pigtail, FC/PC connector	0 to +65

Receiver ordering information

Part Number	Typical Rate (NRZ Mb/s)	Sensitivity (dBm)	Interface Type	Operating Temperature (°C)
RT 2000PT-052FC	52	-40	50/125 pigtail, FC/PC connector	-40 to +85
RT 2000PT-155FC	155	-38	50/125 pigtail, FC/PC connector	-40 to +85
RT 2000PT-622FC	622	-32	50/125 pigtail, FC/PC connector	-40 to +85

Note:
FC/PC connectors on the fiber pigtail are standard. Other connector types such as SC/PC are available through the sales department.

Laser Diode Incorporated
4 Olsen Avenue, Edison, New Jersey 08820 USA
Voice: 732-549-9001, Fax: 732-906-1559
Internet: www.laserdiode.com
e-mail: sales@laserdiode.com

Receivers

...continued on inside overleaf.

The Airpak 2000 Series receivers are high-performance cost-effective optical modules optimized for use in SONET and SDH systems. The wide dynamic range transimpedance design accepts a maximum optical input power of 0 dBm while giving excellent sensitivity of -40 dBm at 52 Mb/s, -38 dBm at 155 Mb/s and -32 dBm at 622 Mb/s. A single +5 volt supply is required without the need for additional negative detector bias. However, to use the optical power-monitor function and to enhance sensitivity at 622 Mb/s, a negative voltage may be applied through Pin 10 of the module. Data outputs are differential PECL compatible. This highly compact receiver complies with an industry standard, 20-pin, dual-in-line footprint and has a multimode fiber pigtail, making it compatible with both singlemode and multimode systems.

Functional Description

Optical Front-end

The optical front-end consists of an InGaAs photodetector coupled to a wide dynamic range transimpedance amplifier for low noise and high bandwidth. An internal AGC circuit allows for input power up to 0 dBm.

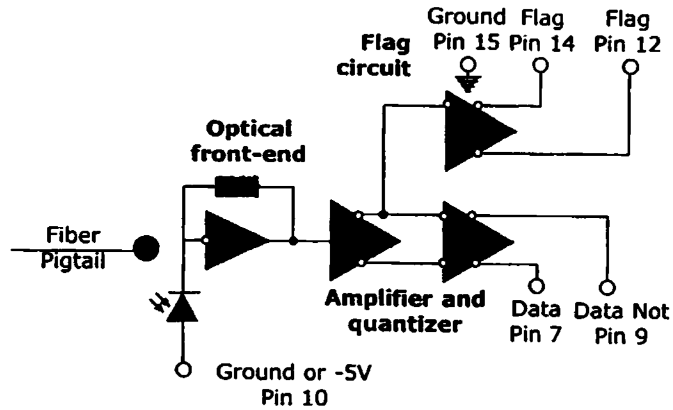
Amplifier and Quantizer

The amplifier stage has high gain and limits large-amplitude signals to maintain wide dynamic range.

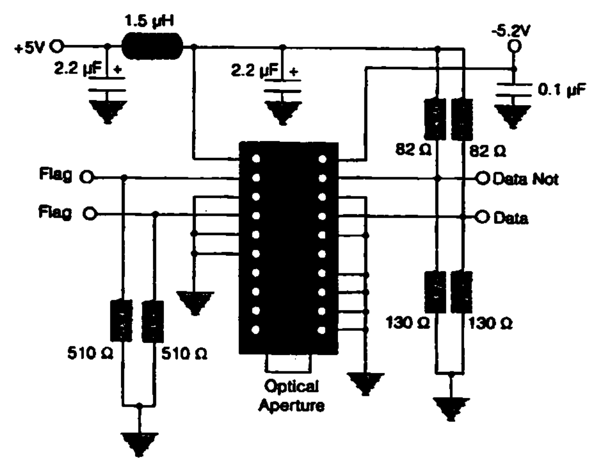
...continued on inside overleaf.

data rates of 52, 155, 622 Mb/s
1310 nm and 1550 nm operation
single 5-volt capable
high sensitivity
high overload power
wide dynamic range
differential data and flag outputs

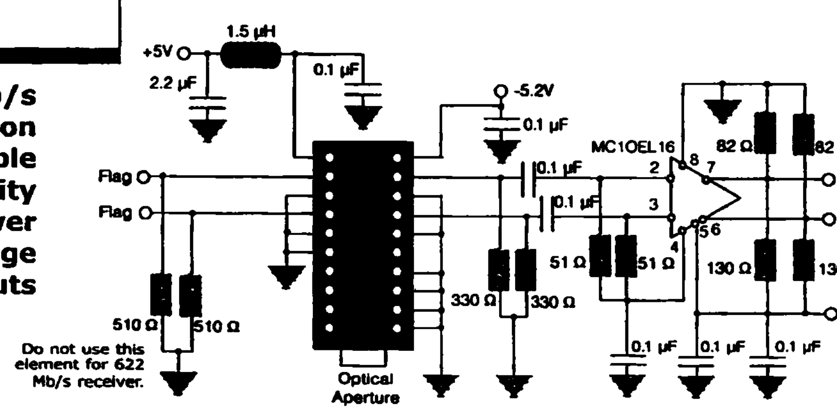
Receiver Functional Diagram



Recommended Receiver Bias for PECL Applications



Recommended Receiver Bias for ECL Applications



HTC Series - Hybrid Temperature Controllers

HTC-1500 / HTC-3000

General Description

The advanced and reliable circuitry of the HTC series easily achieves 0.001°C temperature stability. Its small, low profile package is ideal for designs with space constraints. The linear, PI control loop and bipolar current source are manufactured on a hybrid substrate to maximize performance.

The HTC temperature controllers are easily configured for any design. Virtually any type of temperature sensor can be used with the HTC and a built in sensor bias current source simplifies use with resistive temperature sensors. The independently adjustable Proportional Gain (P) and Integrator Time Constant (I) can be modified to optimize temperature overshoot and stability.

Other features offer added flexibility. A single resistor sets the maximum output current to your load. Add a low current silicon diode to operate resistive heaters with a unipolar output current. An onboard reference voltage simplifies potentiometer control of the temperature setpoint. You can also choose to operate remotely with an external setpoint voltage. Two monitor pins provide access to the temperature setpoint voltage and the actual sensor voltage.

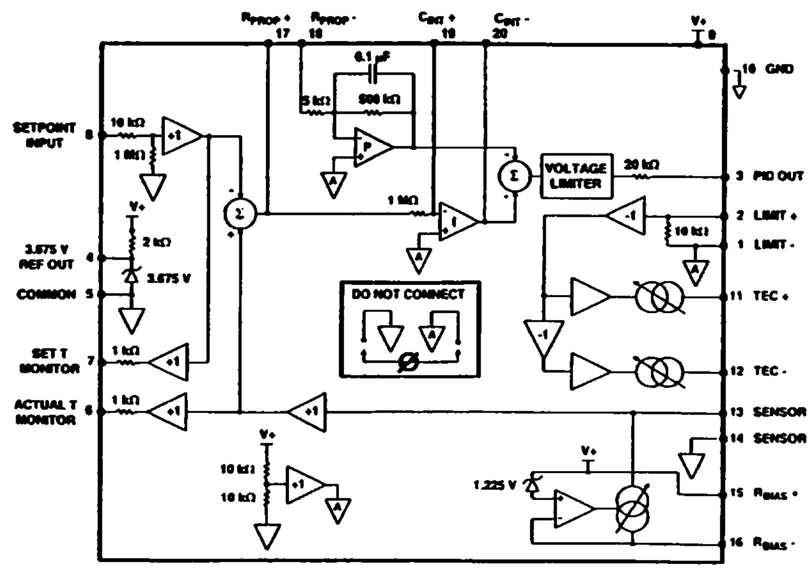
Features

- Compact Size - 1.5 and 3.0 Amp Models
- Interfaces with Thermistors, IC Sensors, & RTDs
- Single supply operation +5 V to +12 VDC
- Greater than +8 V compliance with +12 V input
- Stabilities to < 0.001°C - even at ambient
- Temperature Setpoint, Output Current Limit, Sensor Bias, Proportional Gain, and Integrator Time Constant User Adjustable
- Monitor outputs for Temperature Setpoint and Actual Temperature
- Linear Bipolar or Unipolar Output- operates thermoelectrics or resistive heaters
- Two Year Warranty

Ordering Information

HTC-1500	1.5 A Temperature Controller
HTC-3000	3.0 Amp Temperature Controller
HTCPCB-1500	HTC-1500 mounted to evaluation PCB
HTCPCB-3000	HTC-3000 mounted to evaluation PCB
PWRPAK-5V	+5V @ 8A Power Supply

Functional Diagram



PLD Series +5V Laser Diode Drivers

PLD-200 / PLD-500 / PLD-5000

General Description

The **PLD** series of Laser Diode Drivers combines the high performance you expect from a Wavelength component with two distinct improvements: low voltage operation from +5 V DC, and an **Active Current Limit**.

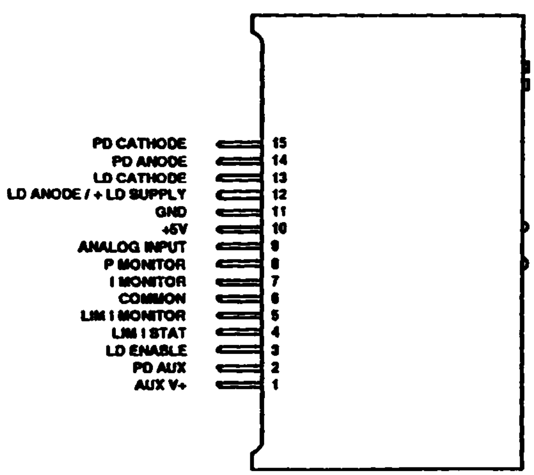
Operating from a single +5 V supply minimizes heat dissipation. Modular packaging makes it easier to integrate the PLD into your system. For applications that require lasers in series, a separate laser diode power supply input lets you provide a higher compliance voltage. The **Active Current Limit** not only protects your laser diode, but ensures that you are operating with maximum stability. When the laser current reaches the level set by the Limit I Trimpot, the output disables and the Limit LED and Limit Status indicate the current limit has been reached.

Two photodiode ranges provide variable sensitivities for optimum operation. You can maintain excellent stability when operating in constant current, constant power, or modulated mode. All trimpots and switches are easily accessible and offer precision control. A slow start circuit, mechanical shorting relay, and Active Current Limit offer maximum protection for your laser diode even when power is removed.

Ordering Information

PLD-200	200 mA Laser Diode Driver
PLD-500	500 mA Laser Diode Driver
PLD-5000	5 Amp Laser Diode Driver
PLDPCB-200	PLD-200 mounted to evaluation PCB
PLDPCB-500	PLD-500 mounted to evaluation PCB
PLDPCB-5000	PLD-5000 mounted to evaluation PCB
PWRPAK-5V	+5V @ 8A Power Supply

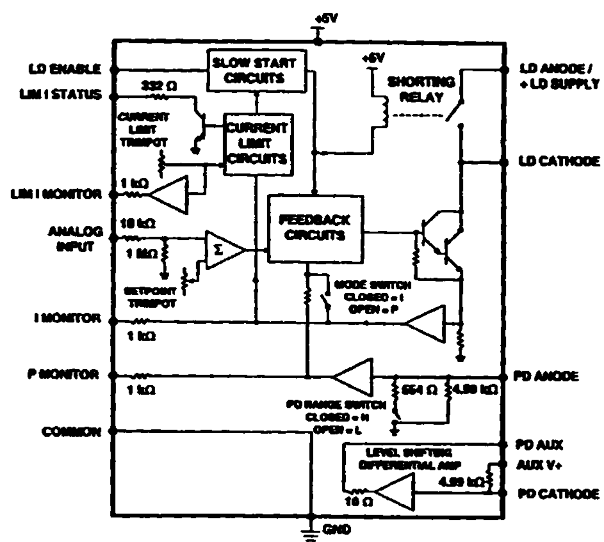
Pin Descriptions



Features

- 200 mA, 500 mA, and 5 Amp models
- Single supply operation: +5 VDC
- < 20 ppm constant current stability (24 hours)
- < 0.02% constant power stability (24 hours)
- Separate Laser Diode Supply input allows for flexible compliance voltages up to +28 VDC typical
- Manually adjust:
  - Setpoint & Current Limit
  - Constant Current or Constant Power Operation
  - Photodiode Sensitivity
- Remotely:
  - Adjust Setpoint Current with Analog Input
  - Enable or Disable Output
  - Monitor Laser Diode Current, Photodiode Current, and Laser Diode Limit Current
  - Monitor Limit Status
- Supports all laser diode / photodiode pin configurations
- Safety is maximized:
  - Slow start circuitry
  - Mechanical relay protects even when power is removed
  - Active Current Limit
- Integral Heatsink (Fan Assembly included with PLD-5000)
- Two Year Warranty

Functional Diagram



19-1311; Rev 1; 3/98

EVALUATION KIT AVAILABLE

MAXIM

+3.3V, 622Mbps SDH/SONET Laser Driver with Automatic Power Control

MAX3667

General Description

The MAX3667 is a complete, +3.3V laser driver with automatic power control (APC), designed for SDH/SONET applications up to 622Mbps. It accepts differential PECL inputs, provides single-ended bias and modulation currents, and operates over a -40°C to +85°C temperature range.

A temperature-stabilized reference voltage simplifies laser current programming. It allows external programming of the modulation current between 5mAp-p and 60mAp-p, and of the bias current between 5mA and 90mA.

The APC function, which incorporates a monitor photodiode, an external resistor, and two external capacitors, maintains constant laser output power. Two current monitors provide high-speed signals that are directly proportional to the bias and modulation currents. Additional features include disable/enable control and a slow-start feature with a minimum turn-on time of 50ns. The MAX3667 is available in die form and in a 32-pin TQFP package.

Applications

622Mbps SDH/SONET Access Nodes

Laser Driver Transmitters

Section Repeaters

Features

- Single +3.3V or +5.0V Operation
- Automatic Average Power Control
- Bias Current and Modulation Current Monitor Outputs
- TTL-Compatible Disable Input
- Temperature-Compensated Reference
- PECL-Compatible Data Inputs

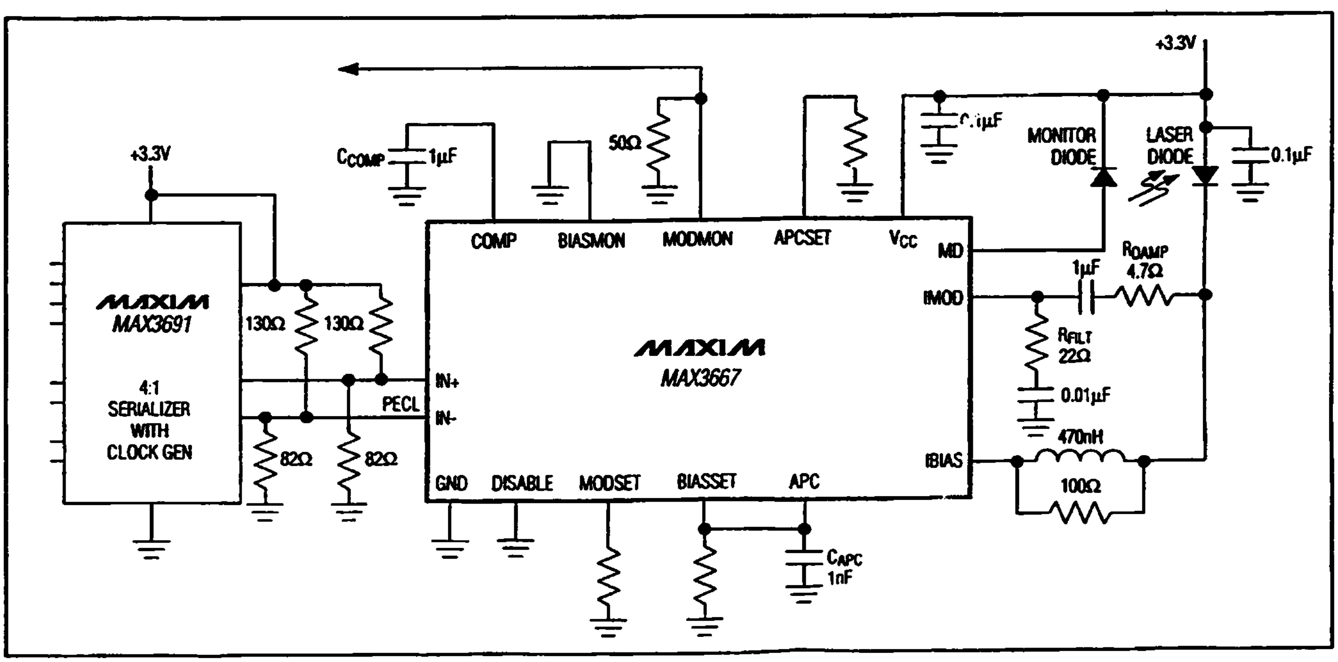
Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX3667ECJ	-40°C to +85°C	32 TQFP
MAX3667E/D	-40°C to +85°C	Dice*

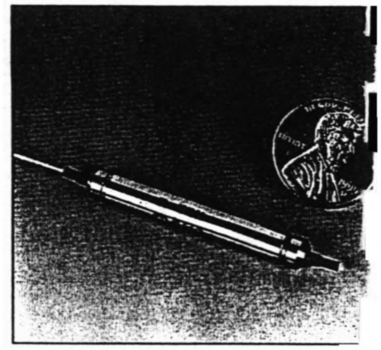
*Dice are designed to operate from -40°C to +85°C but are tested and guaranteed only at T_j = +25°C.

Pin Configuration appears at end of data sheet.

Typical Operating Circuit



BANDPASS WAVELENGTH DIVISION MULTIPLEXER (BWDM) *1533 / 1557nm - 3 ports*



The 3-port, 2-channel bandpass wavelength division multiplexer BWDM uses interference filter technology to separate and multiplex optical transmission signals. The wide, flat passband filter is used for bi-directional WDM networks. It is epoxy-free in the optical path.

SPECIFICATIONS

				Unit		
Pass Channel	Center Wavelength (λc)			nm	1533	1557
	Pass Channel (-0.5dB) Bandwidth	①↔③	Min.	nm	7	
Reflect Channel	Center Wavelength	①↔②		nm	1557	1533
	Bandwidth	①↔②		nm	1553.5~1560.5	1529.5~1536.5
Insertion Loss (λc)†	Pass	①↔③	Typ.	dB	0.8	
			Max.	dB	1.0	
	Reflect	①↔②	Typ.	dB	0.4	
			Max.	dB	0.6	
Isolation (λc)	Pass	①↔②	Min.	dB	10	
	Reflect	①↔③	Min.	dB	40	
Directivity		②↔③	Min.	dB	55	
Optical Return Loss†			Min.	dB	50	
Polarization Dependent Loss (PDL)			Max.	dB	0.1	
Thermal Stability				dB/°C	0.005	
Thermal Wavelength Drift			Max.	nm/°C	0.004	
Optical Power			Max.	mW	250	
Tensile Load			Max.	N	5	
Operating Temperature				°C	0 to +65	
Storage Temperature				°C	-40 to +85	

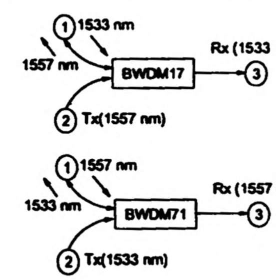
† Without connectors

FEATURES

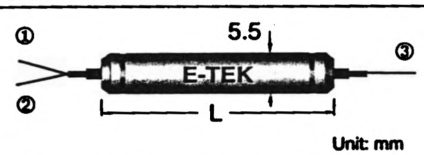
- Wide signal pass bandwid[th]
- High channel isolation
- High return loss
- Low insertion loss
- Low PDL
- Excellent stability and reliability
- Epoxy free optical path

APPLICATIONS

- Optical transceiver
- Bi-directional WDM netw[ork]
- Optical fiber amplifiers
- CATV



PACKAGE DIMENSIONS



ORDERING INFORMATION

B W D M ☐ ☐ 0 0 3 ☐ 0 ☐ ☐

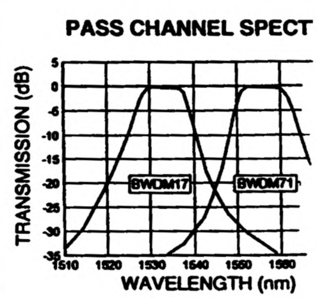
Wavelength
17=pass 1533/reflect 1557
71=pass 1557/reflect 1533

Package
1=5.5mm(ø) x 32mm(L) Corning SMF-28 (250µm)
3=5.5mm(ø) x 40mm(L) Corning SMF-28 (900µm loose tube)

Fiber Length
*1=1 meter
2=2 meters
3=3 meters
4=0.5 meters
5=1.5 meters
6=2.5 meters

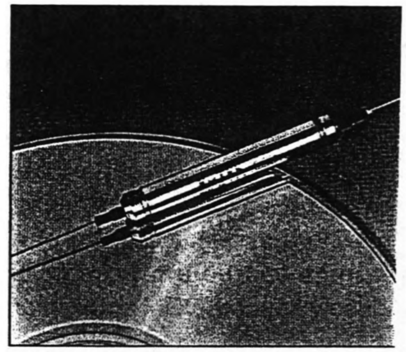
Connector***
*0=None
1=FC/PC
2=FC/SPC
3=FC/APC
4=SC/SPC
5=SC/APC
7=D4
8=ST
9=FC/UPC
A=SC/UPC

* Standard product
*** Insertion loss and return loss will change depending on connector type



DENSE WAVELENGTH DIVISION MULTIPLEXER FILTER (DWFI)

E-TEK's dense ITU wavelength division multiplexer filter DWFI uses thin-film interference coatings to achieve 400 GHz or 200 GHz narrow linewidth channel filtering at ITU wavelengths. Designed specifically for 8-, 16- or 32-channel WDM systems, these 3-port filters have low insertion loss, excellent channel isolation and environmental performance. Completely bi-directional, they can be cascaded in any sequence for a combined multi-wavelength multiplexer or demultiplexer array.



SPECIFICATIONS

Parameter		Port		Unit	200GHz	400GHz
ITU Channels†† (see table)				ch	21, 23, 25, 27, 29, 31, 33, 35, 45, 47, 49, 51, 53, 55, 57, 59	21, 25, 29, 33, 35, 37, 41, 45, 49, 55
Pass Channel Bandwidth (-0.5dB)		①↔③	Min.	nm	±0.25	±0.4
Reflect Channel Bandwidth (-25dB) from λc		①↔②	Min.	nm	±1.3	±2.6
Insertion Loss†	Pass Channel	①↔③	Typ.	dB	1.6	0.8
			Max.	dB	2.0	1.0
	Reflect Channel	①↔②	Typ.	dB	0.6	0.6
			Max.	dB	0.9	0.9
Channel Isolation	Pass Wavelength	①↔②	Min.	dB	9	10
	Reflect Wavelength	①↔③	Min.	dB	25	25
Directivity		②↔③	Min.	dB	45	45
Optical Return Loss†			Min.	dB	45	45
Polarization Dependent Loss (PDL)			Max.	dB	0.1	0.1
Thermal Stability			Max.	dB/°C	0.005	0.005
Thermal Wavelength Drift			Typ.	nm/°C	0.002	0.003
			Max.	nm/°C	0.003	0.004
Optical Power			Max.	mW	250	
Tensile Load			Max.	N	5	
Operating Temperature				°C	0 to +65	
Storage Temperature				°C	-40 to +80	

† Without connectors †† Standard, other ITU wavelengths are also available upon request

FEATURES

- Narrow filter bandwidth
- High wavelength isolation
- High return loss
- Low insertion loss
- Low PDL
- Excellent stability and reliabil
- Epoxy free optical path

APPLICATIONS

- WDM networks
- Optical fiber amplifiers
- CATV

ORDERING INFORMATION

D W F I □ 0 0 0 □□ □ □ □

Channel Spacing
2=200GHz
4=400GHz

Channel Code
ITU frequency code from table on next page.

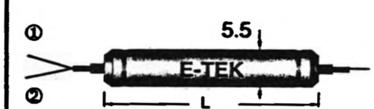
Package
*1=5.5mm(ø) x 32mm(L) Corning SMF-28 (250µm fiber)
3=5.5mm(ø) x 40mm(L) Corning SMF-28 (900µm loose tube)

Fiber Length
*1=1 meter
2=2 meters
3=3 meters
4=0.5 meters
5=1.5 meters
6=2.5 meters

Connector***
*0=None
1=FC/PC
2=FC/SPC
3=FC/APC
4=SC/SPC
5=SC/APC
7=D4
8=ST
9=FC/UPC
A=SC/UPC

*Standard product
***Insertion loss and return loss will change depending on connector type

PACKAGE DIMENSIONS



Unit: m

ORDERING EXAMPLE

200GHz Filter
@191,500GHz (1,565.4961 nm)
D W F I 2 0 0 0 1 5 1 1 0

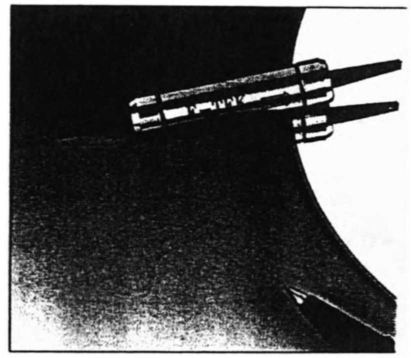
ITU STANDARD FIBER-OPTIC TELECOMMUNICATION CHANNEL: FREQUENCY AND WAVELENGTHS

CH	Frequency (GHz)	Wavelength (nm)	CH	Frequency (GHz)	Wavelength (nm)
15	191,500.0000	1,565.4961	44	194,400.0000	1,542.1425
16	191,600.0000	1,564.6790	45	194,500.0000	1,541.3496
17	191,700.0000	1,563.8628	46	194,600.0000	1,540.5576
18	191,800.0000	1,563.0475	47	194,700.0000	1,539.7663
19	191,900.0000	1,562.2329	48	194,800.0000	1,538.9759
20	192,000.0000	1,561.4193	49	194,900.0000	1,538.1863
21	192,100.0000	1,560.6065	50	195,000.0000	1,537.3974
22	192,200.0000	1,559.7945	51	195,100.0000	1,536.6094
23	192,300.0000	1,558.9834	52	195,200.0000	1,535.8222
24	192,400.0000	1,558.1731	53	195,300.0000	1,535.0358
25	192,500.0000	1,557.3636	54	195,400.0000	1,534.2503
26	192,600.0000	1,556.5550	55	195,500.0000	1,533.4655
27	192,700.0000	1,555.7473	56	195,600.0000	1,532.6815
28	192,800.0000	1,554.9404	57	195,700.0000	1,531.8983
29	192,900.0000	1,554.1343	58	195,800.0000	1,531.1159
30	193,000.0000	1,553.3290	59	195,900.0000	1,530.3344
31	193,100.0000	1,552.5246	60	196,000.0000	1,529.5536
32	193,200.0000	1,551.7210	61	196,100.0000	1,528.7736
33	193,300.0000	1,550.9183	62	196,200.0000	1,527.9944
34	193,400.0000	1,550.1163	63	196,300.0000	1,527.2160
35	193,500.0000	1,549.3153	64	196,400.0000	1,526.4384
36	193,600.0000	1,548.5150	65	196,500.0000	1,525.6616
37	193,700.0000	1,547.7155	66	196,600.0000	1,524.8856
38	193,800.0000	1,546.9169	67	196,700.0000	1,524.1103
39	193,900.0000	1,546.1191	68	196,800.0000	1,523.3359
40	194,000.0000	1,545.3222	69	196,900.0000	1,522.5622
41	194,100.0000	1,544.5260	70	197,000.0000	1,521.7893
42	194,200.0000	1,543.7307	71	197,100.0000	1,521.0200
43	194,300.0000	1,542.9362	72	197,200.0000	1,520.2500

Frequencies are accurate values, wavelengths are dependent on the media properties.

POLARIZATION INSENSITIVE FIBER ISOLATOR (PIFI)

SUPER SERIES



The super series PIFI are two stage isolators with high and very stable isolation over a wide wavelength and temperature range. They are insensitive to the polarization state of the input light and have extremely low PMD.

PERFORMANCE SPECIFICATIONS

Parameter		Unit	Premium Grade	A Grade	B Grade
Peak Isolation	Typ.	dB	58	53	50
Isolation (λ_c ± 30nm, 23°C, SOP)	Min.	dB	46	45	40
Isolation (λ_c, 0~60°C, SOP)	Min.	dB	45	44	40
Insertion Loss (λ_c ± 20nm, 23°C, SOP)†	Typ.	dB	0.4	0.6	0.9
Insertion Loss (λ_c ± 20nm, 23°C, SOP)†	Max.	dB	0.6	0.9	1.5
Return Loss (input/output)† ††	Min.	dB	65 /60	60 /55	60 /50
Polarization Dependent Loss (PDL)††	Max.	dB	0.05	0.15	0.2
Polarization Mode Dispersion (PMD)††	Max.	ps	0.05	0.07	0.15

SOP= All States of Polarization λ_c= Center wavelength
† Without connectors †† Measured at 23°C

OPERATING SPECIFICATIONS

Parameter		Unit	Value
Optical Power	Max.	mW	300
Tensile Load	Max.	N	10
Operating Temperature		°C	-20 to +60
Storage Temperature		°C	-40 to +85†††

††† -20 to 70°C for 3mm cable

QUALIFICATION AND RELIABILITY TESTS

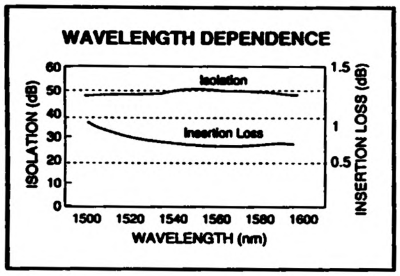
High Temperature Storage Test	85°C for 5,000 hours
Low Temperature Storage Test	-40°C for 5,000 hours
Damp Heat Test	75°C/90% RH for 2,500 hours
Temperature Cycling Test	-40°C/75°C, 500 cycles
Water Immersion Test	43°C for 500 hours
Vibration Test	10~2,000 Hz sinusoidal, 20g, 3 axes
Impact Test	8 drops, 1.8 meters high, 3 axes
Fiber Torsion Test	180° twist, both directions, 5 N force
Fiber Pulling Test	10 N for 250 µm, 20 N for 900 µm, 1 min.

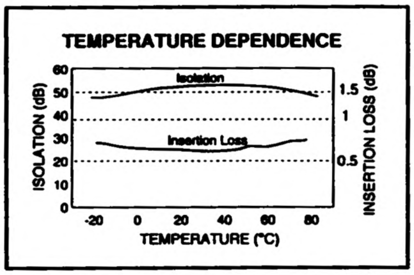
May be manufactured under the following U.S. patents #5,208,876 and 5,317,655

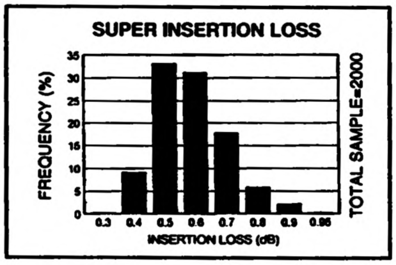
FEATURES
- High Isolation
- Isolation stable over wid temperature/ wavelengtl range
- Low insertion loss
- High return loss
- PMD free
- Excellent stability & reli
- Optical path epoxy free
- Metal bonded package available

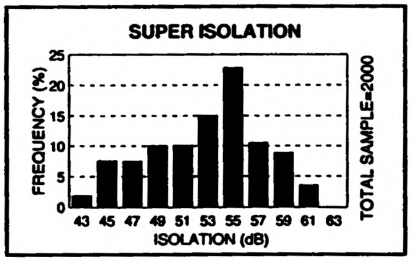
APPLICATIONS
- Optical amplifiers
- CATV fiberoptic links
- Satellite communicatior antenna remoting
- Laser and optical trans testing
- Fiber lasers

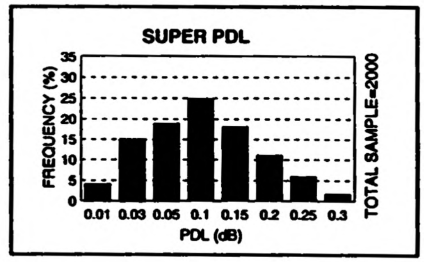
TYPICAL PERFORMANCE DATA

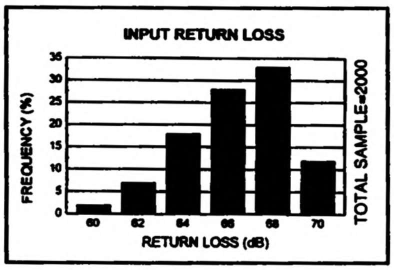


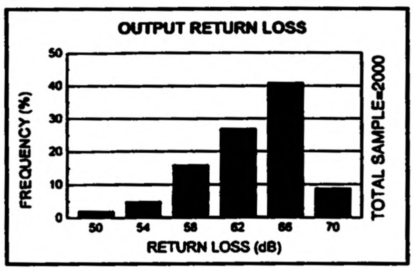


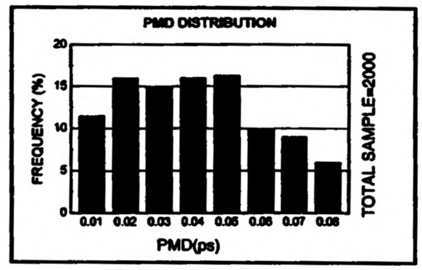






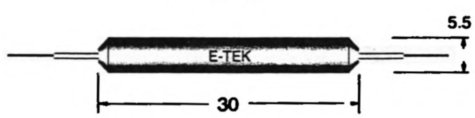






PACKAGE DIMENSIONS

COMPACT



STANDARD

Unit: mm

ORDERING INFORMATION

P I F I [ ] [ ] [ ] S [ ] [ ] [ ] [ ] [ ]

Wavelength
1=1560nm
*2=1550nm
3=1540nm
*4=1480nm
*5=1310nm
6=1300nm

Package
*1=8mm x 34mm
3=Compact
5.5mm x 30mm

Model
P=Premium
*A=A grade
B=B grade

Fiber Type (Input, Output)
1=Corning SMF-28
2=AT&T 100A
3=900μm loose tube (SMF-28)
*4=900μm tight buffer (SMF-28)
5=3mm cable (SMF-28)
**6=Corning SMF-DS fiber (900μm)
**7=Fujikura PM fiber (400μm)

Fiber Length
*1=1 meter
2=2 meters
3=3 meters
4=0.5 meters
5=1.5meters
6=2.5 meters

Connector* (Input, Output)
*0=None
1=FC/PC
2=FC/SPC
3=FC/APC
4=SC/SPC
5=SC/APC
6=Biconic
7=D4
8=ST
9=FC/UPC
A=SC/UPC

* Standard product
** Insertion loss will slightly increase
*** Insertion loss and return loss will change depending on connector type
Note: PM fiber aligned to slow axis

Fiber Optic Isolator Test Data

Sales Order # : 1007542

Type : ● Polarization Insensitive,
0 Single Polarization,
0 LD Interface

Model No. PIFI23A011100

Grade : PIFI
A

Measurement Wavelength : 1550 nm @ Room Temp.

Serial No	I.L (dB)	Iso. (dB)	P.D.L. (dB)	R.L.(I/O) (dB)
62859738	0.38	38.0	0.01	65/65
62861044	0.24	39.0	0.02	63/65

Fiber		
	Input	SMF
	Output	SMF

Fiber (Cable) OD : 250μm

Fiber Length (each end) : 1.0m

Connector : NONE

PASS
INSPECTION
4

Package Size (Body Only) :

5.5±0.1mm(OD)x30±2mm(L)

Tested By : ______________ Date : ____________

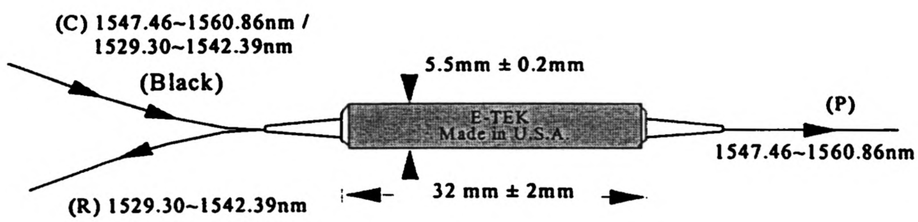
Checked By: ______________ Date : ____________

E-TEK *Dynamics, Inc*
1885 Lundy Ave., San Jose, CA 95131 USA

INSPECTION REPORT

Date: 07/19/99

1. Order-No.: 1007542
2. Item: BWDM540H31010
3. E-TEK Spec Version: Catalog (1999)
4. Serial No.: 62900244
5. Fiber: Corning SMF-28 CPC6 ,250μm fiber
6. Fiber Length (each end): 1m
7. Schematic:



8. Performance (@ 23.0 °C):

Insertion Loss (dB)		Isolation (dB)		Ripple (dB)	
1547.46~1560.86nm (C) ⇒ (P)	1529.30~1542.39nm (C) ⇒ (R)	1529.30~1542.39nm (C) ⇒ (P)	1547.46~1560.86nm (C) ⇒ (R)	1529.30~1542.39nm (C) ⇒ (R)	1547.46~1560.86nm (C) ⇒ (P)
<0.74	<0.19	>30	>10	<0.1	<0.8

PDL (dB)	Directivity (dB)	Return Loss (dB)
<0.1	>50	>50

9. Connectors: None
10. Spectrum Curve attached (1 page)

E-Tek Dynamics, Inc.
1885 Lundy Avenue, San Jose, CA 95131, U.S.A.
Tel. (408) 432-6300 Fax (408) 432-8550

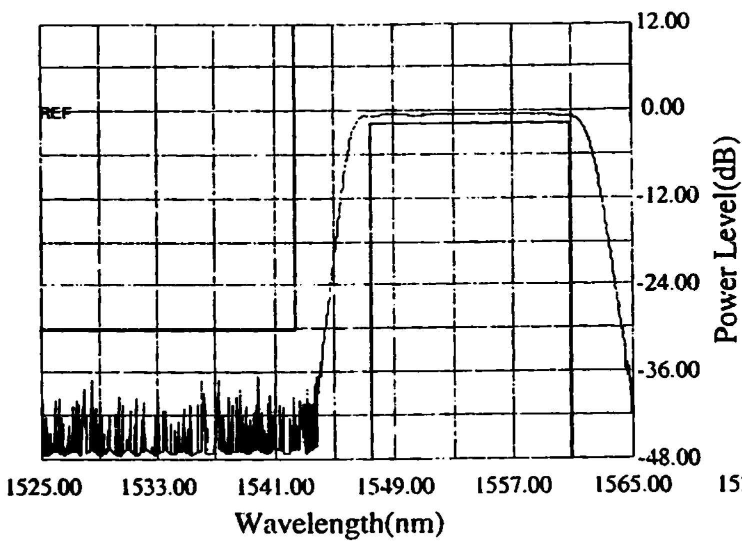
Test by: 1090
Check by: PASS INSPECTION 5

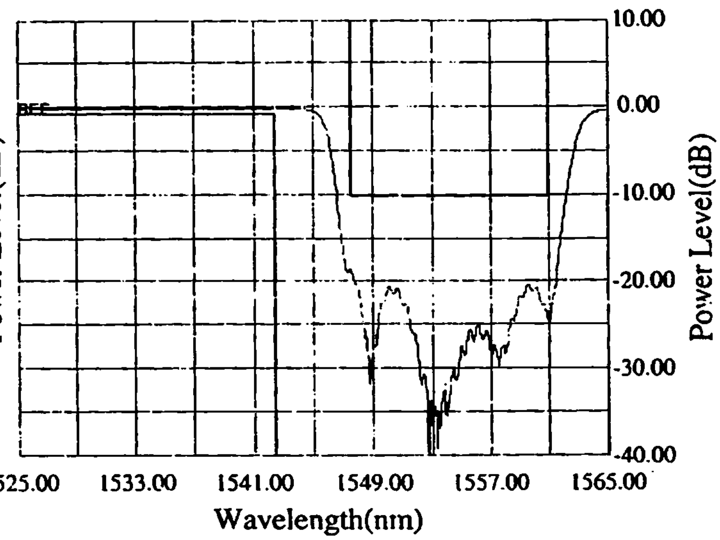
62900244

BWDM Spectrum Performance Test Report

Report Date: 07/17/1999

Order No:		Test No:	1	Operator:	1090
Model #:	BWDM540H31010	Temperature:	23.0	Station:	WDMTEST52
Travel Card #:	b261333	Fail:	/	Test Date:	07/17/1999
Serial #:	62900244	Warning:	—	Test Time:	22:54





Bandpass Performance Test

Center Wavelength & Bandwidth (down from PP -0.51dB)(nm)

dB Down	WLLeft(nm)	WLRgt(nm)	BW(nm)	CW(nm)	Ripple(dB)

Passband Loss & Ripple (IL @ NominalWL 1554.16nm = -0.51dB)(dB)

ILLft(dB)	ILRgt(dB)	ILMax(dB)	ILMin(dB)	Rpl(dB)	WLLft(nm)	WLRt(nm)
-0.70	-0.75	-0.74	-0.51	0.23	1547.46	1560.86

Adjacent Channel Isolation

IsoLeft(dB)	IsoRight(dB)	IsoMin(dB)	MinWL(nm)	WLLeft(nm)	WLRgt(nm)
-46.80	-46.16	-46.16	1542.40	1529.30	1542.39

Notch Performance Test

Center Wavelength & Bandwidth (down from Peak -0.11dB)(nm)

dB Down	WLLeft(nm)	WLRgt(nm)	BW(nm)	CW(nm)	Ripple(dB)

Drop Channel Isolation (dB)

IsoLeft(dB)	IsoRight(dB)	IsoMin(dB)	MinWL(dB)	WLLeft(nm)	WLRgt(nm)
-18.61	-24.24	-18.54	1547.44	1547.46	1560.86

Adjacent Channel Insertion Loss And Ripple (dB)

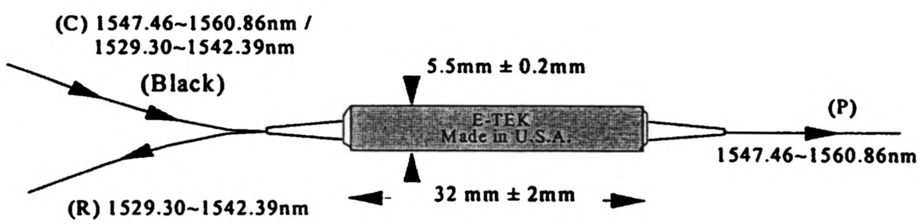
ILLft(dB)	ILRt(dB)	ILMax(dB)	ILMin(dB)	Rpl(dB)	WLLft(nm)	WLRt(nm)
-0.13	-0.18	-0.19	-0.11	0.08	1529.30	1542.39

PASS INSPECTION 5

INSPECTION REPORT

Date: 07/19/99

1. Order-No.: 1007542
2. Item: BWDM540H31010
3. E-TEK Spec Version: Catalog (1999)
4. Serial No.: 62900241
5. Fiber: Corning SMF-28 CPC6 ,250μm fiber
6. Fiber Length (each end): 1m
7. Schematic:



8. Performance (@ 23.0 ^{o}C):

Insertion Loss (dB)		Isolation (dB)		Ripple (dB)	
1547.46~1560.86nm (C) ⇒ (P)	1529.30~1542.39nm (C) ⇒ (R)	1529.30~1542.39nm (C) ⇒ (P)	1547.46~1560.86nm (C) ⇒ (R)	1529.30~1542.39nm (C) ⇒ (R)	1547.46~1560.86nm (C) ⇒ (P)
<0.61	<0.42	>30	>10	<0.1	<0.8

PDL (dB)	Directivity (dB)	Return Loss (dB)
<0.1	>50	>50

9. Connectors: None
10. Spectrum Curve attached (1 page)

E-Tek Dynamics, Inc.
1885 Lundy Avenue, San Jose, CA 95131, U.S.A.
Tel. (408) 432-6300 Fax (408) 432-8550

Test by: 1090
Check by: PASS INSPECTION 5

62900241

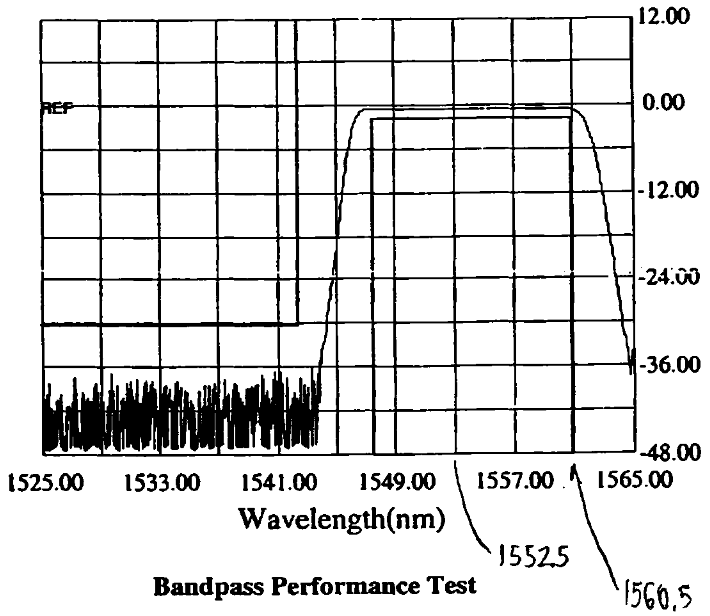
BWDM Spectrum Performance Test Report

Report Date: 07/17/1999

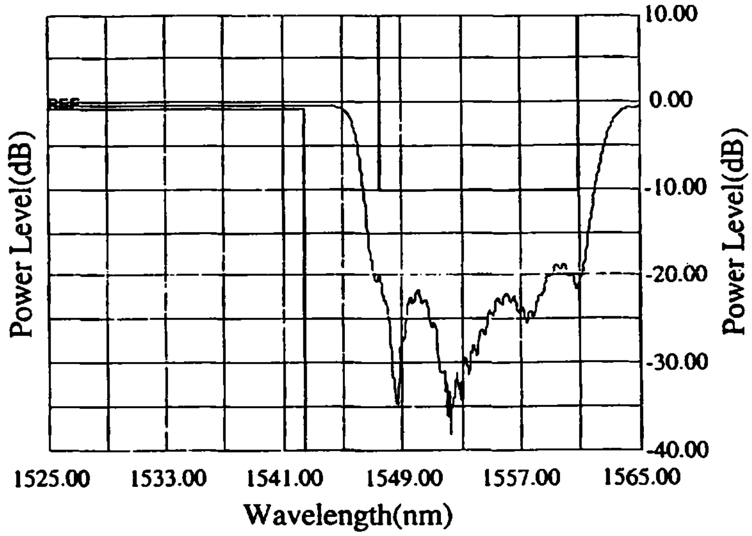
Order No:
Model #: **BWDM540H31010**
Travel Card #: **b261339**
Serial #: **62900241**

Test No: **1**
Temperature: **23.0**
Fail: /
Warning: —

Operator: **1090**
Station: **WDMTEST52**
Test Date: **07/17/1999**
Test Time: **23:08**



Bandpass Performance Test



Notch Performance Test

Center Wavelength & Bandwidth (down from PP -0.42dB)(nm)

dB Down	WLLeft(nm)	WLRgt(nm)	BW(nm)	CW(nm)	Ripple(dB)

Center Wavelength & Bandwidth (down from Peak -0.36dB)(nm)

dB Down	WLLeft(nm)	WLRgt(nm)	BW(nm)	CW(nm)	Ripple(dB)

Passband Loss & Ripple (IL @ NominalWL 1554.16nm = -0.42dB)(dB)

ILLft(dB)	ILRgt(dB)	ILMax(dB)	ILMin(dB)	Rpl(dB)	WLLft(nm)	WLRt(nm)
-0.52	-0.62	-0.61	-0.42	0.19	1547.46	1560.86

Drop Channel Isolation (dB)

IsoLeft(dB)	IsoRight(dB)	IsoMin(dB)	MinWL(dB)	WLLeft(nm)	WLRgt(nm)
-19.90	-20.79	-18.31	1559.88	1547.46	1560.86

Adjacent Channel Isolation

IsoLeft(dB)	IsoRight(dB)	IsoMin(dB)	MinWL(nm)	WLLeft(nm)	WLRgt(nm)
-46.89	-46.25	-46.25	1542.40	1529.30	1542.39

Adjacent Channel Insertion Loss And Ripple (dB)

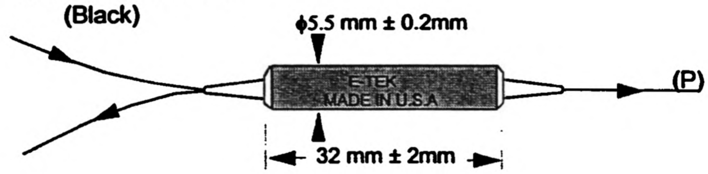
ILLft(dB)	ILRt(dB)	ILMax(dB)	ILMin(dB)	Rpl(dB)	WLLft(nm)	WLRt(nm)
-0.37	-0.41	-0.42	-0.36	0.06	1529.30	1542.39

PASS INSPECTION 5

INSPECTION REPORT

Date: 08/07/99

1. Order-No.: 1007542
2. Item: DWFI400059110
3. E-TEK Spec Version: Catalog (1999)
4. Serial No.: 62765639
5. Fiber: Corning SMF-28 CPC6, 250μm bare fiber.
6. Fiber Length (each end): 1 m
7. Schematic:



8. Performance (@ 23.0 ^{o}C)

(Center Wavelength: 1530.33nm)

Insertion Loss (dB)		Isolation (dB)	
1529.93 ~ 1530.73nm (C) ⇒ (P)	1500.00~ 1527.63nm& 1533.03 ~1600.00nm (C) ⇒ (R)	1529.93 ~ 1530.73nm (C) ⇒ (R)	1500.00~ 1527.63nm & 1533.03 ~1600.00nm (C) ⇒ (P)
<0.63	<0.22	>10	>25

PDL (dB)	Directivity (dB)	Return Loss (dB)
<0.1	>45	>45

9. Connectors: None
10. Spectrum Curve attached (1 Page)

E-TEK Dynamics, Inc.
Lundy Avenue, San Jose, CA 95131, U.S.A.
Tel. (408) 432-6300 Fax: (408) 432-8550

Test by: PASS INSPECTION 1386
Check by: 5

BWDM Spectrum Performance Test Report

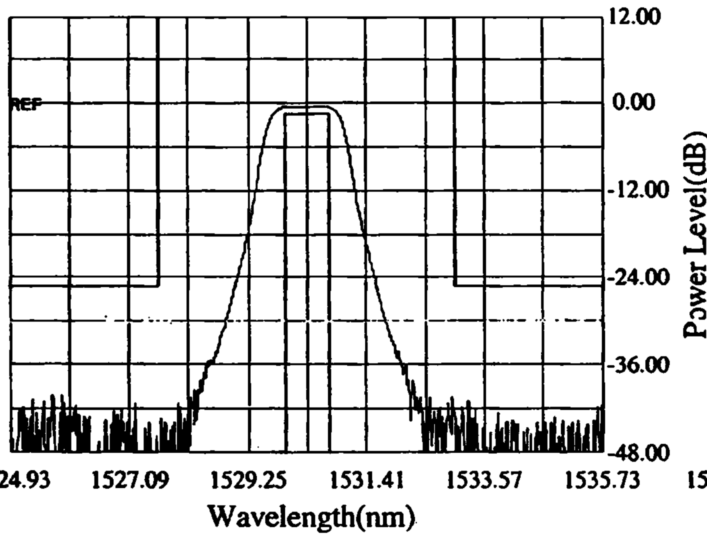
62765639

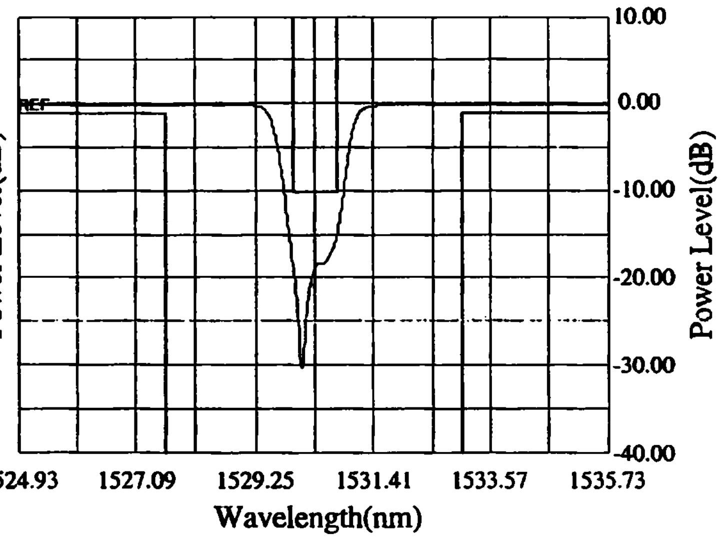
Report Date: 08/09/1999

Order No:
Model #: **DWFI400059110**
Travel Card #: **B219081**
Serial #: **62765639**

Test No: **1**
Temperature: **23.0**
Fail: /
Warning: —

Operator: **1386**
Station: **WDMTEST41**
Test Date: **08/09/1999**
Test Time: **10:50**





Bandpass Performance Test

Center Wavelength & Bandwidth (down from PP -0.43dB)(nm)

dB Down	WLLeft(nm)	WLRgt(nm)	BW(nm)	CW(nm)	Ripple(dB)
-0.30	1529.83	1530.77	0.95	1530.30	
-0.50	1529.78	1530.82	1.04	1530.30	
-1.00	1529.72	1530.89	1.17	1530.30	
-16.00	1529.28	1531.32	2.04	1530.30	

Passband Loss & Ripple (IL @ NominalWL 1530.33nm = -0.47dB)(dB)

ILLft(dB)	ILRgt(dB)	ILMax(dB)	ILMin(dB)	Rpl(dB)	WLLft(nm)	WLRt(nm)
-0.52	-0.63	-0.63	-0.43	0.20	1529.93	1530.73

Adjacent Channel Isolation

IsoLeft(dB)	IsoRight(dB)	IsoMin(dB)	MinWL(nm)	WLLeft(nm)	WLRgt(nm)
-49.63	-50.69	-50.69	1527.63	1524.93	1527.63
-43.62	-41.20	-40.68	1533.27	1533.03	1535.73

Notch Performance Test

Center Wavelength & Bandwidth (down from Peak -0.19dB)(nm)

dB Down	WLLeft(nm)	WLRgt(nm)	BW(nm)	CW(nm)	Ripple(dB)

Drop Channel Isolation (dB)

IsoLeft(dB)	IsoRight(dB)	IsoMin(dB)	MinWL(dB)	WLLeft(nm)	WLRgt(nm)
-18.41	-15.13	-15.13	1530.73	1529.93	1530.73

Adjacent Channel Insertion Loss And Ripple (dB)

ILLft(dB)	ILRt(dB)	ILMax(dB)	ILMin(dB)	Rpl(dB)	WLLft(nm)	WLRt(nm)
-0.19	-0.20	-0.21	-0.19	0.02	1524.93	1527.63
-0.22	-0.21	-0.22	-0.20	0.02	1533.03	1535.73

PASS
INSPECTION
5

INSPECTION REPORT

Date: 07/19/99

1. Order-No.: 1007542

2. Item: DWFI400053110

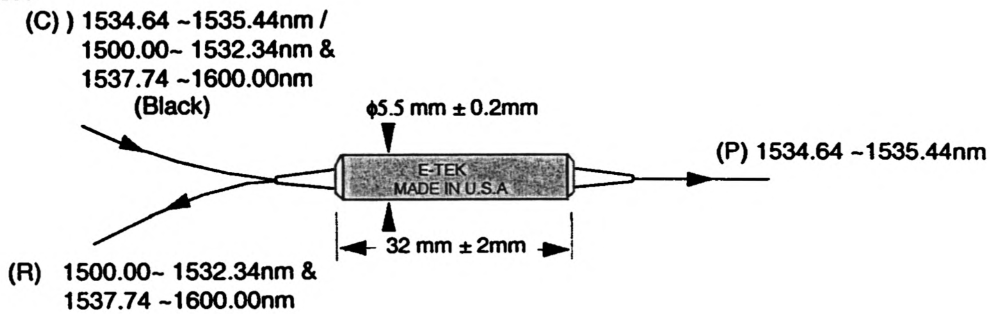
3. E-TEK Spec Version: Catalog (1999)

4. Serial No.: 62900481

5. Fiber: Corning SMF-28 CPC6, 250μm bare fiber.

6. Fiber Length (each end): 1 m

7. Schematic:



8. Performance (@ 23.0 ^{O}C)
(Center Wavelength: 1535.04nm)

Insertion Loss (dB)		Isolation (dB)	
1534.64 ~1535.44nm (C) ⇒ (P)	1500.00~ 1532.34nm & 1537.74 ~1600.00nm (C) ⇒ (R)	1534.64 ~1535.44nm (C) ⇒ (R)	1500.00~1532.34nm & 1537.74 ~1600.00nm (C) ⇒ (P)
<0.72	<0.36	>10	>25

PDL (dB)	Directivity (dB)	Return Loss (dB)
<0.1	>45	>45

9. Connectors: None

10. Spectrum Curve attached (1 Page)

E-TEK Dynamics, Inc.
Lundy Avenue, San Jose, CA 95131, U.S.A.
Tel. (408) 432-6300 Fax: (408) 432-8550

Test by: PASS 665
Check by: INSPECTION 5

62900481

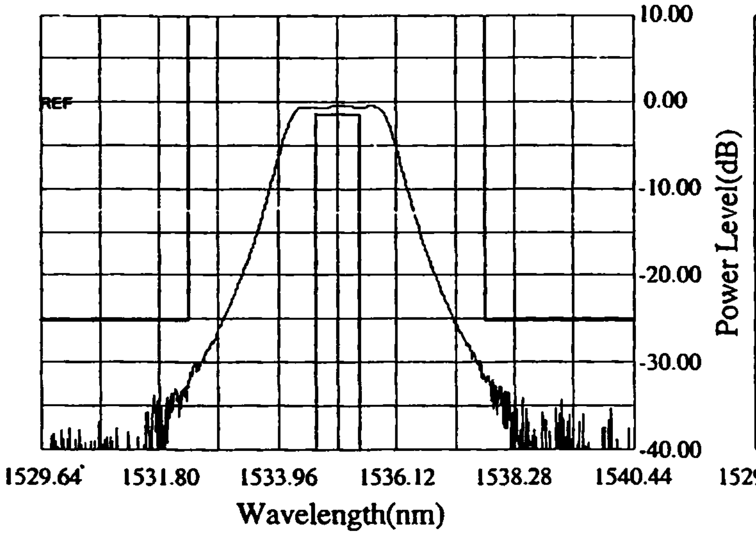
BWDM Spectrum Performance Test Report

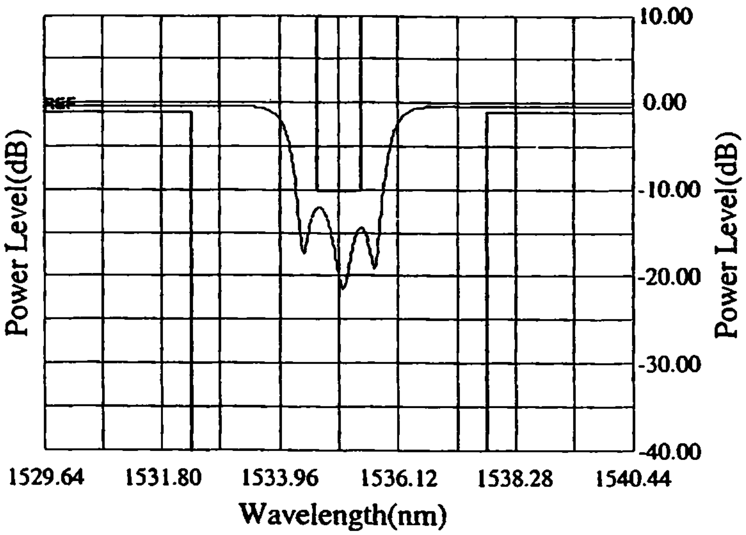
Report Date: 07/17/1999

Order No:
Model #: **DWFI400053110**
Travel Card #: **b240129**
Serial #: **62900481**

Test No: **1**
Temperature: **23.0**
Fail: /
Warning: —

Operator: **1665**
Station: **WDMTEST51**
Test Date: **07/17/1999**
Test Time: **12:50**





Bandpass Performance Test

Center Wavelength & Bandwidth (down from PP -0.42dB)(nm)

dB Down	WLLeft(nm)	WLRgt(nm)	BW(nm)	CW(nm)	Ripple(dB)
-0.30	1534.68	1535.80	1.11	1535.24	0.16
-0.50	1534.29	1535.83	1.54	1535.06	0.30
-1.00	1534.24	1535.89	1.66	1535.07	0.30
-16.00	1533.51	1536.62	3.11	1535.07	0.30

Passband Loss & Ripple (IL @ NominalWL 1535.04nm = -0.44dB)(dB)

ILLft(dB)	ILRgt(dB)	ILMax(dB)	ILMin(dB)	Rpl(dB)	WLLft(nm)	WLRt(nm)
-0.71	-0.58	-0.72	-0.42	0.30	1534.64	1535.44

Adjacent Channel Isolation

IsoLeft(dB)	IsoRight(dB)	IsoMin(dB)	MinWL(nm)	WLLeft(nm)	WLRgt(nm)
-43.45	-31.84	-31.84	1532.34	1529.64	1532.34
-31.31	-43.79	-31.08	1537.79	1537.74	1540.44

Notch Performance Test

Center Wavelength & Bandwidth (down from Peak -0.31dB)(nm)

dB Down	WLLeft(nm)	WLRgt(nm)	BW(nm)	CW(nm)	Ripple(dB)

Drop Channel Isolation (dB)

IsoLeft(dB)	IsoRight(dB)	IsoMin(dB)	MinWL(dB)	WLLeft(nm)	WLRgt(nm)
-11.84	-14.12	-11.71	1534.68	1534.64	1535.44

Adjacent Channel Insertion Loss And Ripple (dB)

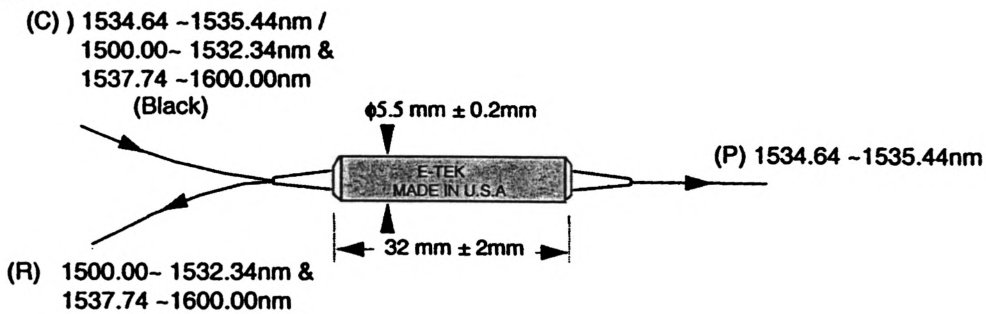
ILLft(dB)	ILRt(dB)	ILMax(dB)	ILMin(dB)	Rpl(dB)	WLLft(nm)	WLRt(nm)
-0.35	-0.36	-0.36	-0.32	0.04	1529.64	1532.34
-0.34	-0.32	-0.35	-0.31	0.04	1537.74	1540.44

PASS
INSPECTION
5

INSPECTION REPORT

Date: 07/19/99

1. Order-No.: 1007542
2. Item: DWFI400053110
3. E-TEK Spec Version: Catalog (1999)
4. Serial No.: 62900482
5. Fiber: Corning SMF-28 CPC6, 250μm bare fiber.
6. Fiber Length (each end): 1 m
7. Schematic:



8. Performance (@ 23.0 °C)
(Center Wavelength: 1535.04nm)

Insertion Loss (dB)		Isolation (dB)	
1534.64 ~1535.44nm (C) ⇒ (P)	1500.00~ 1532.34nm & 1537.74 ~1600.00nm (C) ⇒ (R)	1534.64 ~1535.44nm (C) ⇒ (R)	1500.00~1532.34nm & 1537.74 ~1600.00nm (C) ⇒ (P)
<0.60	<0.27	>10	>25

PDL (dB)	Directivity (dB)	Return Loss (dB)
<0.1	>45	>45

9. Connectors: None
10. Spectrum Curve attached (1 Page)

E-TEK Dynamics, Inc.
Lundy Avenue, San Jose, CA 95131, U.S.A.
Tel. (408) 432-6300 Fax: (408) 432-8550

Test by: 1665
Check by: PASS INSPECTION 5

BWDM Spectrum Performance Test Report

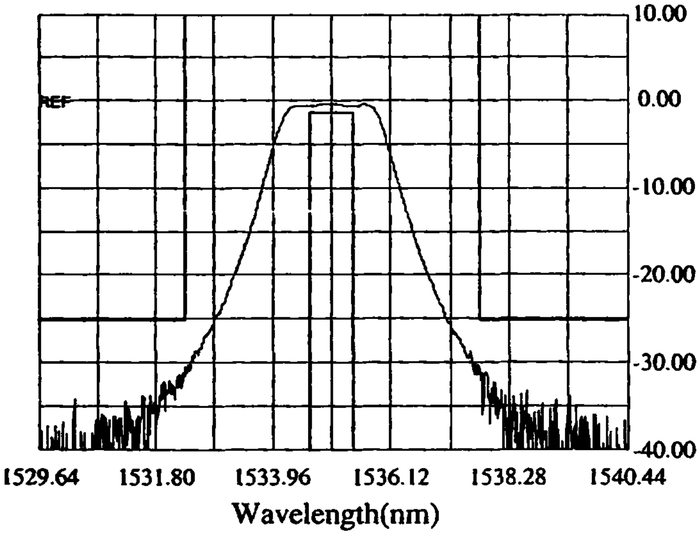
62900482

Report Date: 07/17/1999

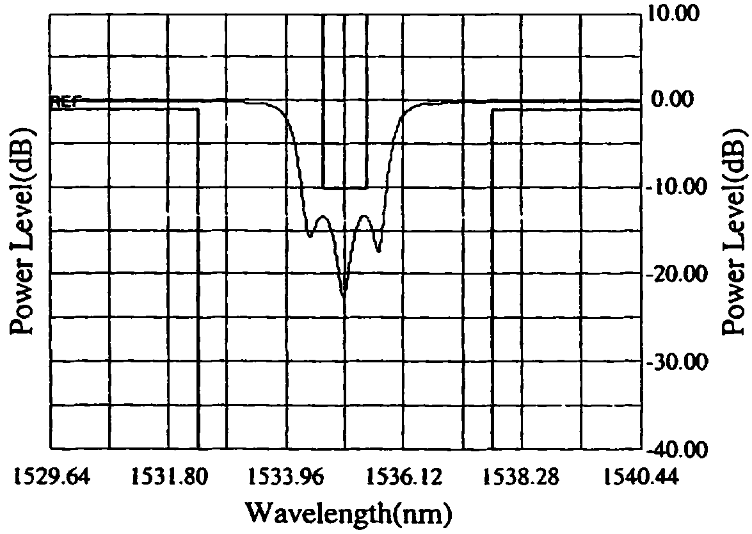
Order No:
Model #: **DWFI400053110**
Travel Card #: **b240123**
Serial #: **62900482**

Test No: **1**
Temperature: **23.0**
Fail: /
Warning: —

Operator: **1665**
Station: **WDMTEST51**
Test Date: **07/17/1999**
Test Time: **12:44**



Bandpass Performance Test



Notch Performance Test

Center Wavelength & Bandwidth (down from PP -0.39dB)(nm)

dB Down	WLLeft(nm)	WLRgt(nm)	BW(nm)	CW(nm)	Ripple(dB)
-0.30	1534.33	1535.75	1.42	1535.04	0.22
-0.50	1534.28	1535.79	1.51	1535.04	0.22
-1.00	1534.22	1535.85	1.64	1535.03	0.22
-16.00	1533.46	1536.59	3.13	1535.02	0.22

Center Wavelength & Bandwidth (down from Peak -0.21dB)(nm)

dB Down	WLLeft(nm)	WLRgt(nm)	BW(nm)	CW(nm)	Ripple(dB)

Passband Loss & Ripple (IL @ NominalWL 1535.04nm = -0.40dB)(dB)

ILLft(dB)	ILRgt(dB)	ILMax(dB)	ILMin(dB)	Rpl(dB)	WLLft(nm)	WLRt(nm)
-0.59	-0.59	-0.60	-0.39	0.21	1534.64	1535.44

Drop Channel Isolation (dB)

IsoLeft(dB)	IsoRight(dB)	IsoMin(dB)	MinWL(dB)	WLLeft(nm)	WLRgt(nm)
-13.22	-13.32	-13.18	1535.40	1534.64	1535.44

Adjacent Channel Insertion Loss And Ripple (dB)

ILLft(dB)	ILRt(dB)	ILMax(dB)	ILMin(dB)	Rpl(dB)	WLLft(nm)	WLRt(nm)
-0.25	-0.23	-0.27	-0.21	0.06	1529.64	1532.34
-0.25	-0.25	-0.27	-0.23	0.04	1537.74	1540.44

Adjacent Channel Isolation

IsoLeft(dB)	IsoRight(dB)	IsoMin(dB)	MinWL(nm)	WLLeft(nm)	WLRgt(nm)
-40.33	-30.00	-30.00	1532.34	1529.64	1532.34
-30.71	-43.82	-30.69	1537.77	1537.74	1540.44

PASS
INSPECTION
5

INSPECTION REPORT

Date: 08/07/99

1. Order-No.: 1007542

2. Item: DWFI400059110

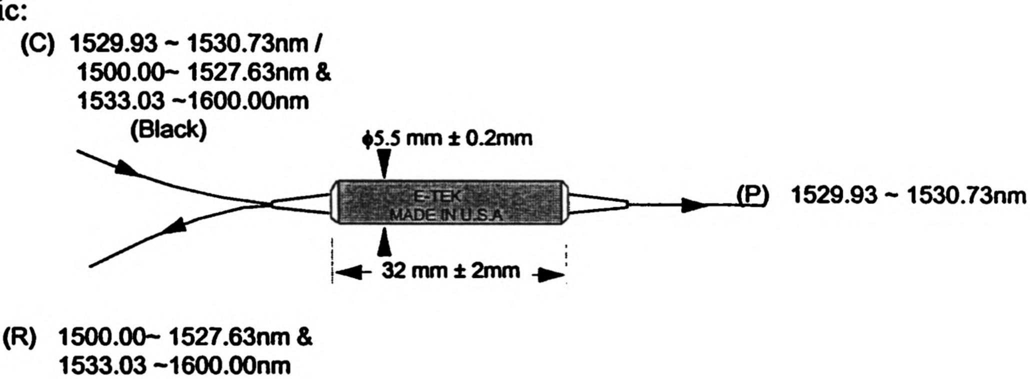
3. E-TEK Spec Version: Catalog (1999)

4. Serial No.: 62765631

5. Fiber: Corning SMF-28 CPC6, 250μm bare fiber.

6. Fiber Length (each end): 1 m

7. Schematic:



8. Performance (@ 23.0 °C)

(Center Wavelength: 1530.33nm)

Insertion Loss (dB)		Isolation (dB)	
1529.93 ~ 1530.73nm (C) ⇒ (P)	1500.00~ 1527.63nm& 1533.03 ~1600.00nm (C) ⇒ (R)	1529.93 ~ 1530.73nm (C) ⇒ (R)	1500.00~ 1527.63nm & 1533.03 ~1600.00nm (C) ⇒ (P)
<0.97	<0.26	>10	>25

PDL (dB)	Directivity (dB)	Return Loss (dB)
<0.1	>45	>45

9. Connectors: None

10. Spectrum Curve attached (1 Page)

E-TEK Dynamics, Inc.
Lundy Avenue, San Jose, CA 95131, U.S.A.
Tel. (408) 432-6300 Fax: (408) 432-8550

Test by: 1386

Check by:

PASS INSPECTION 5

BWDM Spectrum Performance Test Report

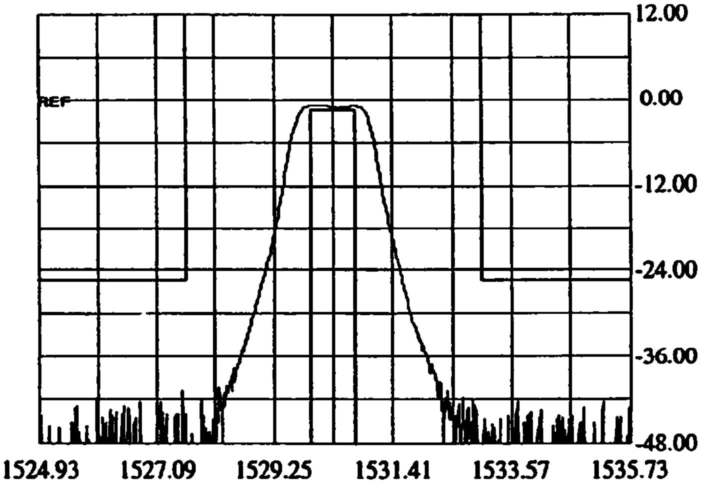
62765631

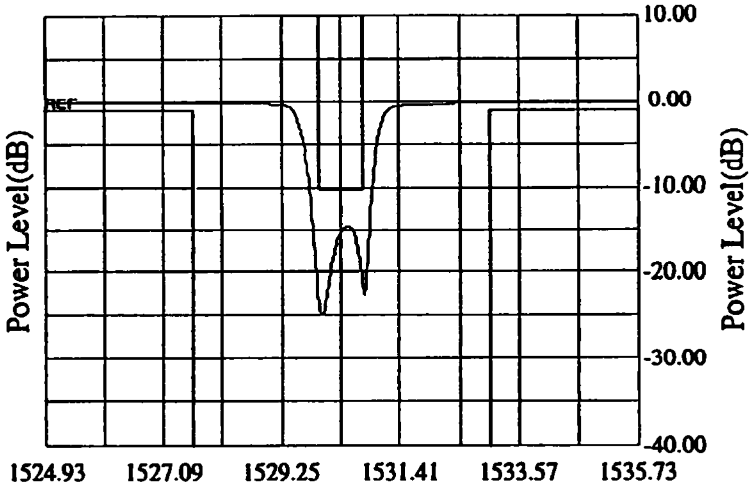
Report Date: 08/09/1999

Order No:
Model #: DWFI400059110
Travel Card #: B219093
Serial #: 62765631

Test No: 1
Temperature: 23.0
Fail: /
Warning: —

Operator: 1386
Station: WDMTEST41
Test Date: 08/09/1999
Test Time: 10:59





Bandpass Performance Test

Center Wavelength & Bandwidth (down from PP -0.80dB)(nm)

dB Down	WLLeft(nm)	WLRgt(nm)	BW(nm)	CW(nm)	Ripple(dB)
-0.30	1529.82	1530.84	1.02	1530.33	0.17
-0.50	1529.79	1530.87	1.09	1530.33	0.17
-1.00	1529.74	1530.92	1.19	1530.33	0.17
-16.00	1529.31	1531.33	2.02	1530.32	0.17

Passband Loss & Ripple (IL @ NominalWL 1530.33nm = -0.94dB)(dB)

ILLft(dB)	ILRgt(dB)	ILMax(dB)	ILMin(dB)	Rpl(dB)	WLLft(nm)	WLRt(nm)
-0.84	-0.88	-0.97	-0.80	0.17	1529.93	1530.73

Adjacent Channel Isolation

IsoLeft(dB)	IsoRight(dB)	IsoMin(dB)	MinWL(nm)	WLLeft(nm)	WLRgt(nm)
-48.35	-50.32	-50.32	1527.63	1524.93	1527.63
-50.69	-42.34	-41.42	1533.67	1533.03	1535.73

Notch Performance Test

Center Wavelength & Bandwidth (down from Peak -0.24dB)(nm)

dB Down	WLLeft(nm)	WLRgt(nm)	BW(nm)	CW(nm)	Ripple(dB)

Drop Channel Isolation (dB)

IsoLeft(dB)	IsoRight(dB)	IsoMin(dB)	MinWL(dB)	WLLeft(nm)	WLRgt(nm)
-23.53	-21.21	-14.35	1530.45	1529.93	1530.73

Adjacent Channel Insertion Loss And Ripple (dB)

ILLft(dB)	ILRt(dB)	ILMax(dB)	ILMin(dB)	Rpl(dB)	WLLft(nm)	WLRt(nm)
-0.25	-0.25	-0.26	-0.24	0.02	1524.93	1527.63
-0.26	-0.25	-0.26	-0.24	0.02	1533.03	1535.73

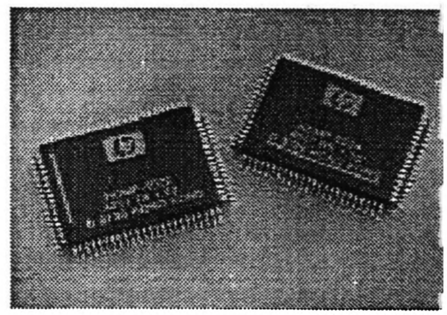
PASS
INSPECTION
5

HEWLETT PACKARD

Low Cost Gigabit Rate Transmit/Receive Chip Set with TTL I/Os

Technical Data

HDMP-1022 Transmitter
HDMP-1024 Receiver



Features

- **Virtual Ribbon Cable Replacement**
- **On-Chip Encode / Decode**
- **On-Chip State Machine for Fully Automatic Link Management**
- **On-Chip Tx/Rx PLL Provides Frame Synchronization**
- **High Speed Serial Rate** 150-1500 MBaud (User Selectable)
- **Standard TTL Interface** 16, 17, 20, or 21 Bits Wide
- **Implemented in a Low Cost Aluminum M-Quad 80 Package**

Applications

- **Backplane Serialization/ Bus Extender**
- **Video, Image Acquisition**
- **Point to Point Data Links**
- **Implement SCI-FI Standard**
- **Implement Serial HIPPI Specification**

Description

The HDMP-1022 transmitter and the HDMP-1024 receiver are used to build a high-speed data link for point-to-point communication. The monolithic silicon bipolar transmitter chip and receiver chip are each provided in a standard aluminum M-Quad 80 package.

From the user's viewpoint, these products can be thought of as providing a "virtual ribbon cable" interface for the transmission of data. Parallel data (a frame) loaded into the Tx (transmitter) chip is delivered to the Rx (receiver) chip over a serial channel, which can be either a coaxial copper cable or optical link, and is reconstructed into its original parallel form.

The chip set hides from the user all the complexity of encoding, multiplexing, clock extraction, demultiplexing and decoding. Unlike other links, the phase-locked-loop clock extraction circuit also transparently provides for frame synchronization–the user is not troubled with the periodic insertion of frame synchronization words. In addition, the DC balance of the line code is automatically maintained by the chip set. Thus, the user can transmit arbitrary data without restriction. The Rx chip also includes a state-machine controller (SMC) that provides a startup handshake protocol for the duplex link configuration.

The serial data rate of the Tx/Rx link is selectable in four ranges (see tables on page 5), and extends from 120 Mbits/s up to 1.25 Gbits/s. This translates into an encoded serial rate of 150-1500 MBaud. The parallel data interface is 16 or 20 bit TTL, pin selectable. A flag bit is available and can be used as an extra 17th or 21st bit under the user's control. The flag bit can also be used as an even or odd frame indicator for dual-frame transmission. If not used, the link performs expanded error detection.

The serial link is synchronous, and both frame synchronization and bit synchronization are maintained. When data is not available to send, the link maintains synchronization by transmitting fill frames. Two (training) fill frames are reserved for handshaking during link startup

User control space is also supported. If Control Available (CAV) is asserted at the Tx chip, the least significant 14 or 18 bits of the data are sent and the Rx Control Available (CAV) line will indicate the data as a Control Word.

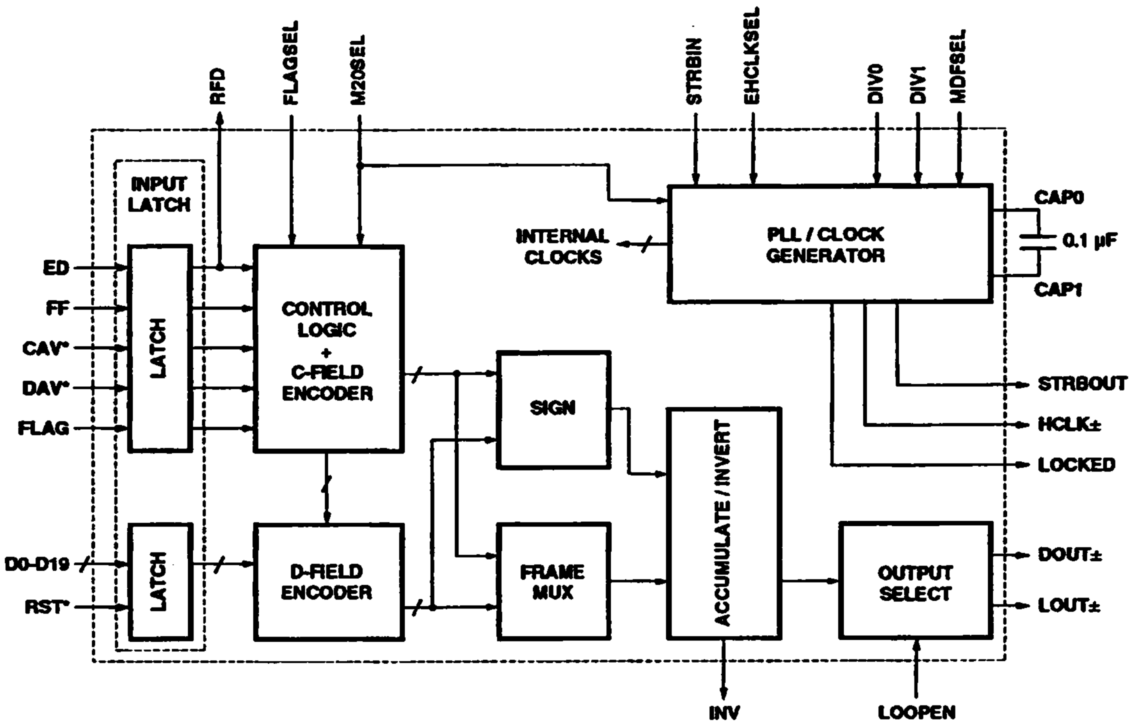


Figure 4. HDMP-1022 Transmitter Block Diagram.

HDMP-1022 Tx Block Diagram

The HDMP-1022 was designed to accept 16 or 20 bit wide parallel data (frames) and transmit it over a high speed serial line. Many of the link management functions are integrated into the HDMP-1022, thereby greatly minimizing the design effort. The HDMP-1022 performs the following functions:

- Parallel Word Input
- High Speed Clock Multiplication
- Frame Encoding
- Parallel to Serial Multiplexing

PLL/Clock Generator

The Phase Locked Loop and Clock Generator are responsible for generating all internal clocks needed by the transmitter to perform its functions. These clocks are based on a supplied frame clock (STRBIN) and control signals (M20SEL, MDFSEL, EHCLKSEL, DIV1, DIV0). In single frame mode (MDFSEL=0), STRBIN is expected to be the incoming frame clock. The PLL/Clock Generator locks on to this incoming rate and multiplies the clock up to the needed high speed serial clock. Based on M20SEL, which determines whether the incoming data frame is 16 or 20 bits wide, the PLL/Clock Generator multiplies the frame rate clock by 20 or 24 respectively (data bits + 4 control bits). DIV1/DIV0 are set to inform the transmitter of the frequency range of the incoming data frames. The internal frame rate clock is accessible through STRBOUT Z'd the high speed serial clock is accessible through HCLK.

When MDFSEL is set high, the transmitter is in Double Frame Mode. Using this option, the user may send a 32 or 40 bit wide data frame in two segments while supplying the original 32 or 40 bit frame clock at STRBIN. Doubling of the frame rate is performed by the transmitter. The clock generator section performs the clock multiplication to the necessary serial clock rate.

By setting EHCLKSEL high, the user may provide an external TTL serial clock at STRBIN. This clock replaces the internal VCO clock and is intended for diagnostic purposes only. This clock is used directly by the high speed serial circuitry to output the serial data at speeds that are not within the VCO range. This signal is not characterized.

Control Logic and C-Field Encoder

The Control Logic is responsible for determining what information is serially sent to the output. If CAV* is low, it sends the data at D0..D8 and D9..D17 as control word information regardless of the state of DAV*. If CAV* is high and DAV* is low, it sends parallel

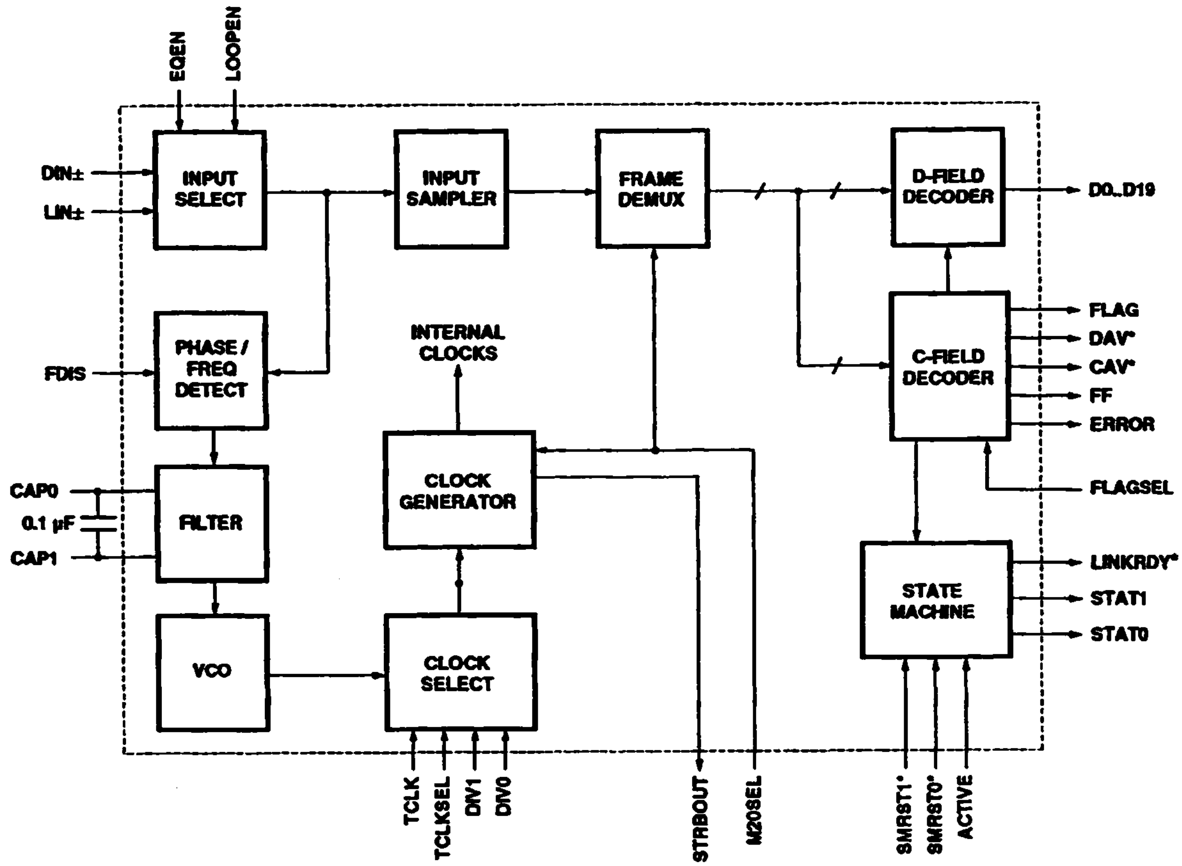


Figure 5. HDMP-1024 Receiver Block Diagram.

HDMP-1024 Rx Block Diagram

The HDMP-1024 receiver was designed to convert a serial data signal sent from the HDMP-1022 into either 16,17, 20, or 21 bit wide parallel data. In doing this, it performs the functions of

- Clock Recovery
- Data Recovery
- Demultiplexing
- Frame Decoding
- Frame Synchronization
- Frame Error Detection
- Link State Control

Input Select

The input select block determines which input line is used. In normal operation (LOOPEN=0), DIN is accepted as the input signal. For improved distance and BER using coax cable, an input equalizer may be used by asserting EQEN. By setting LOOPEN high, the receiver accepts LIN as the input signal. This feature allows for loop back testing exclusive of the transmission medium.

Phase/Frequency Detect

This block compares either the phase or the frequency of the incoming signal to the internal serial clock generated from the Clock Select block. The frequency detect disable pin (FDIS) is set high to disable the frequency detector and enable the phase detector. See *HDMP-1024 (Rx) Phase Locked Loop* for more details. The output of this block, PH1, is used by the filter to determine the control signal for the VCO.

Filter

This is a loop filter that accepts the PH1 output from the Phase/ Frequency Detector and converts it into a control signal for the VCO. This control signal tells the VCO whether to increase or decrease its frequency. The Filter uses the PH1 input to determine a proportional signal and an integral signal. The proportional signal determines whether the VCO should increase or decrease its frequency. The integral signal filters out the high frequency PH1 signal and stores a historical PH1 output level. The two signals combined determine the magnitude of frequency change of the VCO.

VCO

This is the Voltage Controlled Oscillator that is controlled by the output of the Filter. It outputs a high speed digital signal to the Clock Select.

Appendix II: Link Configuration Examples

This section shows some application examples using the HDMP-1022/1024 chipset. Refer to *I/O Definition* for detailed circuit-level interconnections.

This guide is intended to aid the user in designing G-LINK into a system. It provides the necessary details of getting the system up, without the detailed description of the inner circuitry of the chip set.

The first section is a description of the various configurations for duplex and simplex operation. The second section describes the interface to both single frame and double frame mode. Following that is a section on the integrating capacitor and power supply bypassing recommendations. Next is a guide to the various types of electrical I/O connections. Also included is a list of the various options and their definitions.

Duplex/Simplex Configurations

The following describes the common setups for the link. In all cases, the DIN and LIN are differential high speed lines, and unused leads should be terminated with 50 Ω AC coupled to ground. Since the data stream has no DC component, a coupling cap of 0.1 μF is recommended for the DIN and LIN inputs.

Full Duplex

Figure 16 shows HDMP-1022/1024 in a full duplex configuration connecting two bidirectional (parallel) buses. Each end of the link has a Tx and Rx pair. The receiver's state machine outputs (STAT0 and STAT1) are used to control the status of the link. Various options such as 16/20 bit mode (M20SEL) and speed selections (DIV0,DIV1) are grouped together under the label 'options.' A power-on reset is available to the user to reset the link during startup.

When the Tx has acquired lock to the incoming STRBIN at the frame rate, the LOCKED pin is activated, which enables the Rx. At this state, both STAT0 and STAT1 are low, forcing the Tx to send FF0, which is a square wave pattern used by the remote Rx to acquire frame lock. When the local Rx has acquired frame lock, STAT1 is set high to first turn off its own frequency detector (FDIS), then self sets to active mode (ACTIVE), and tells the local Tx to send FF1 to signal the remote Rx that the local pair is ready. Likewise, when the remote pair is ready, the local Rx will receive FF1, causing STAT0 to go high, which asserts the enable data (ED) pin on the Tx. The ED signal is retimed to signify to the host that the Tx is ready to send

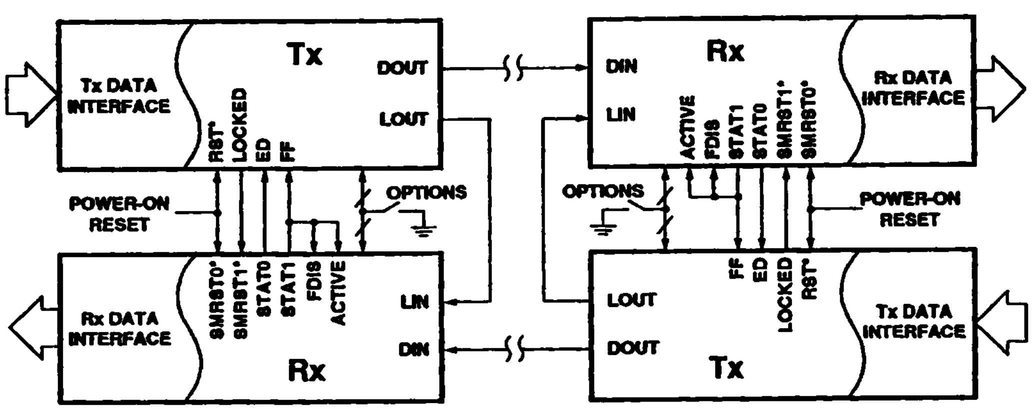
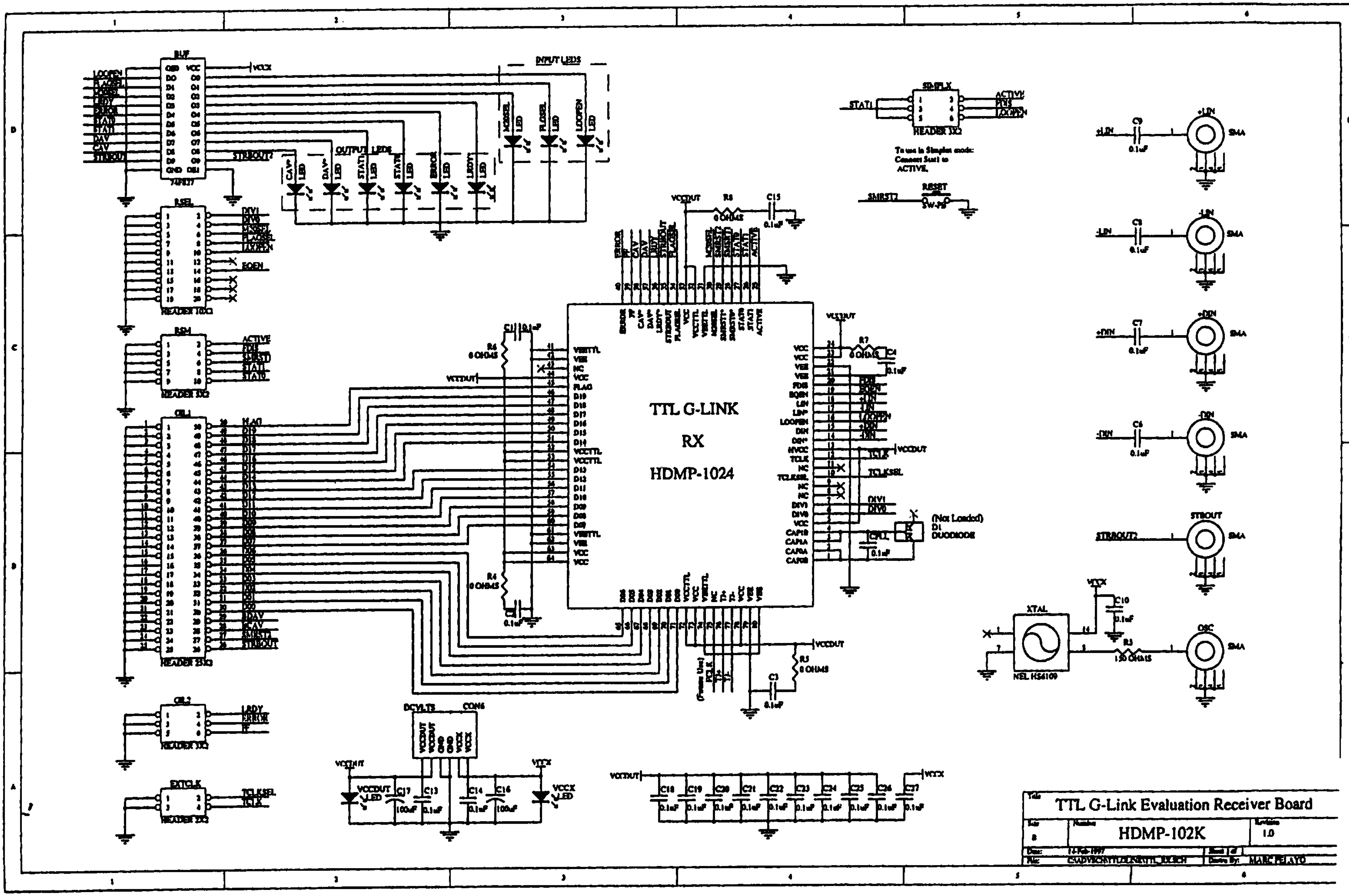
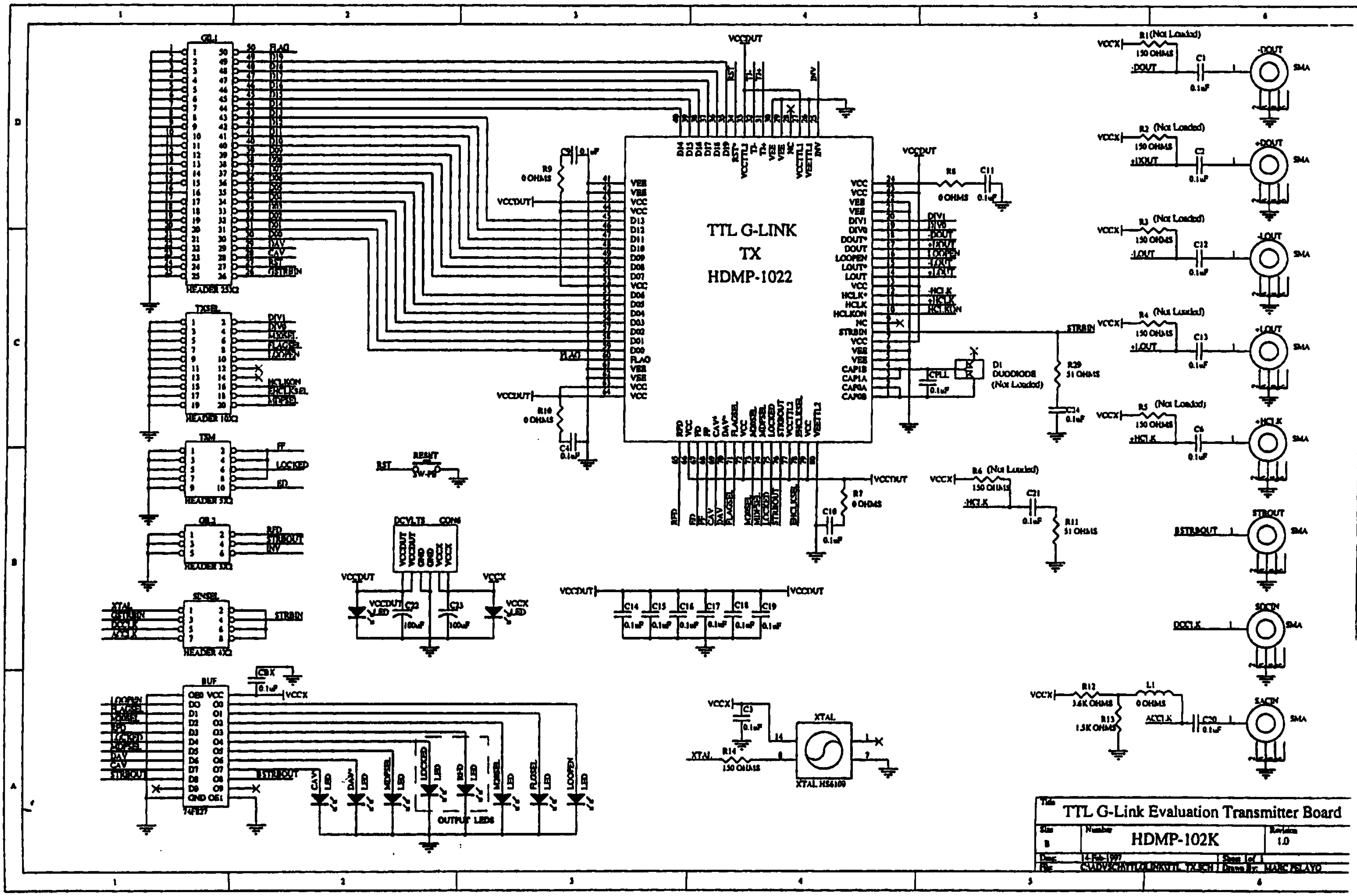


Figure 16. Full Duplex Configuration.



TTL G-LINK
RX
HDMP-1024
BUF
74F827
INPUT LEDS
OUTPUT LEDS
SIMPLX
HEADER 3X2
To use in Simplex mode: Connect Stat1 to ACTIVE.
RESET
SW-PB
RSEL
HEADER 10X2
RSM
HEADER 5X2
OBL1
HEADER 25X2
OBL2
HEADER 3X2
EXTCLK
HEADER 2X2
DCVLTS
CON6
XTAL
NEL HS4109
(Not Loaded)
D1
DUODIODE
SMA
Title
TTL G-Link Evaluation Receiver Board
Size
B
Number
HDMP-102K
Revision
1.0
MARC PELAYO


TTL G-LINK
TX
HDMP-1022
HEADER 25X2
HEADER 10X2
HEADER 5X2
HEADER 3X2
HEADER 4X2
74F827
OUTPUT LEDS
XTAL HS6100
TTL G-Link Evaluation Transmitter Board
HDMP-102K
1.0
14-Feb-1997
MARC PELAYO

Proposal Section
TITLE
PROJECT OVERVIEW
BACKGROUND INFORMATION/ STATEMENT OF THE PROBLEM
PROJECT DETAIL*
- Goals & Objectives
- Clientele
- Methods
- Staff/Administration
AVAILABLE RESOURCES
NEEDED RESOURCES
- Personnel
- Facilities
- Equipment/Supplies/Communication
- Budget
EVALUATION PLAN
APPENDICES

bwaters

Debra