Need for Amplification prior to the Laser Diode in the Fiber-Optic Return Link[1]

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Incorporation of a 8dB amplifier stage consisting of single stage of MSA0520 (HP-Avantek make) before the Laser diode in the return link Laser diode optical Transmitter [OTx(R)] was envisaged and agreed upon on February 10, 1994 during the meeting between S/Shri T.L. Venkatasubramani, D.S. Sivaraj and Shri K.S. Saini. See Annexure 'A' for the minutes of the meeting. With 8dB amplifier included, the configuration proposed (See Fig. 2 of Annexure 'A') -17 dbm operating level per IF channel at the ABR output and -14 dbm level per IF channel at the Laser diode input.

However, an attempt was made to optimise the entire GMRT receiver operating power levels during August 1995. This optimisation proposed an operating level of -20dbm power level at ABR output and -17dbm level at the Laser diode input for each IF channel. The 8db amplifier was included in this optimised configuration. Annexure B1, B2 and B3 shows this optimised level diagrams for a 32 MHz bandwidth from the RF front-end to Fiber-optic return link receiver [ORx(R)].

Fiber-Optic links were designed to have no loss and no gain [Gain of 0db]. In order to adjust the gain for 0db, an attenuator (L_{att}) is varied and adjusted to give 0db net link Gain. This attenuator is placed after the low noise amplifier following the PIN photo diode. See Fig. in Annexure C1. It is obvious from the figure and the noise level table associated with this figure (Annexure C2) that 0db net gain for the link is possible only upto an optical Fiber loss of about 7db. For optical losses more than 7dB, the fiber-optic links will start giving losses. Thus we can conclude that without 8db amplifier, the optical loss is limited to 7db only.

If 8dB amplifier is added, we can have 0db net link loss, for optical losses of up to about 11 dB. Upto 11 dB optical losses are expected in GMRT optical Fiber.

Meanwhile, dynamic range measurements for the receiver chains were done. The mea-

[1] ~SAK/apk.tex

surements indicated that the 1dB compression point of the Antenna Base Receiver (ABR) output is ≃ –5dbm. For the optical Transmitter, OTX(R) and Receiver ORX(R), the upper compression level is limited by the output amplifier and 5 way divider combination and not limited by the laser diode. The measured output 1 dB compression point of the ORX(R) is +2dbm. Since the ABR output 1dB compression is at –5dbm, proposals for lowering the operating IF level from –20 to about –25 were made which means that the corresponding decrease has to be compensated by providing similar increase in the following stages. Without this increase in any of the succeeding stages, the baseband output power level might fall below the ALC knee. Since 8dB amplifier is anyway going to be added in the OTX (R), proposal for providing 12dB amplifier instead of 8dB was made. When 12 dB amplifier is incorporated, the Fiber-optic return link will have a 4dB net gain with this 4dB gain extra, now the ABR output can operate at a level of –24dBm resulting in a better dynamic range. The MMIC for the 12dB amplifier could ideally be Mini Circuits make Model. MAV–11 (10 — 1000 MHz), featuring a 1dB compression point of +17.5dbm and third order intercept point of +30 dbm. Since this MMIC is yet to be obtained, one *can alternatively use Mini-circuits make MAR–3 (DC–2000 MHz) featuring +10dbM 1dB compression point and +23 dbm. Third order intercept point, since the compression is not going to be limited by this MAR–3 amplifier.*

Annexure C-3 and C-4 illustrate the Equivalent System Noise Temperatures including the Baseband system noise contribution at various point of the fiber-optic return link.

In Annexure D, a comparison of system noise and system operating levels is made. EIN OF-BB is the equivalent input system noise at the input of the OTX(R) for 32 MHz Noise Bandwidth. The comparison table indicates that with 12 dB Amplifier, in the OTX(R), ABR can be operated down to -25 dbm levels for a signal to Noise Ratio of 20 dB whereas with 8dB amplifier, ABR output level can operate upto -21 dbm for an SNR of 20 dB.

ANNEXURE-A

Quiescent RF Power Levels at IF-system and Optical system Interface.

(A meeting was held to resolve the issue of Power Levels at the interface, on 10/02/1994. The following were present:)

- T.L.Venkatasubramani
- D.S.Sivaraj
- K.S.Saini

A rough sketch of the components present at the interface is given below. The RF Power levels present at various points are indicated in the diagram. The output of the 5 way combiner is the output of the Remote Receiver Rack which is fed to the Optical Rack. Currently the power level at this point is adjusted to −14dBm/IF channel. This works out at be −20dBm at the laser diode input which is less than the stipulated value of −14dBm.

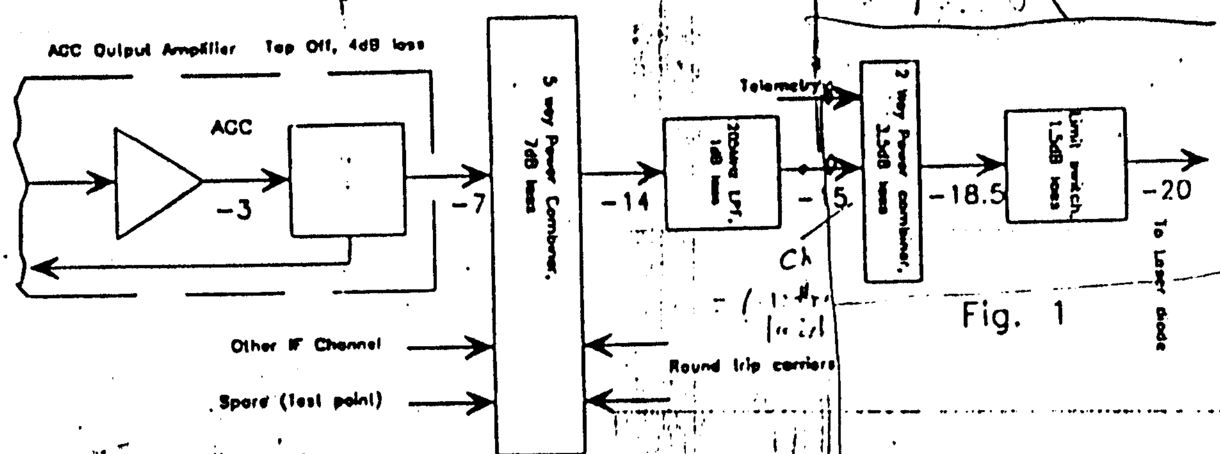


Fig. 1

Fig 1.

With the current operating levels, the final output amplifier of the ACC in the IF system is operating at a level of −3dBm, which corresponds to an IMD performance of −46dBc. If IMD performance is not to be sacrificed, then the deficit of power at the laser diode cannot be made up by shifting the output level of the ACC by 6dB. It was therefore decided to add an 8dB modular amplifier MSA0520 of AVANTEK make (whose compression point is sufficiently high), and reduce the IF gain and the ACC operating level by 2dB. This gives the required operating levels as shown below:

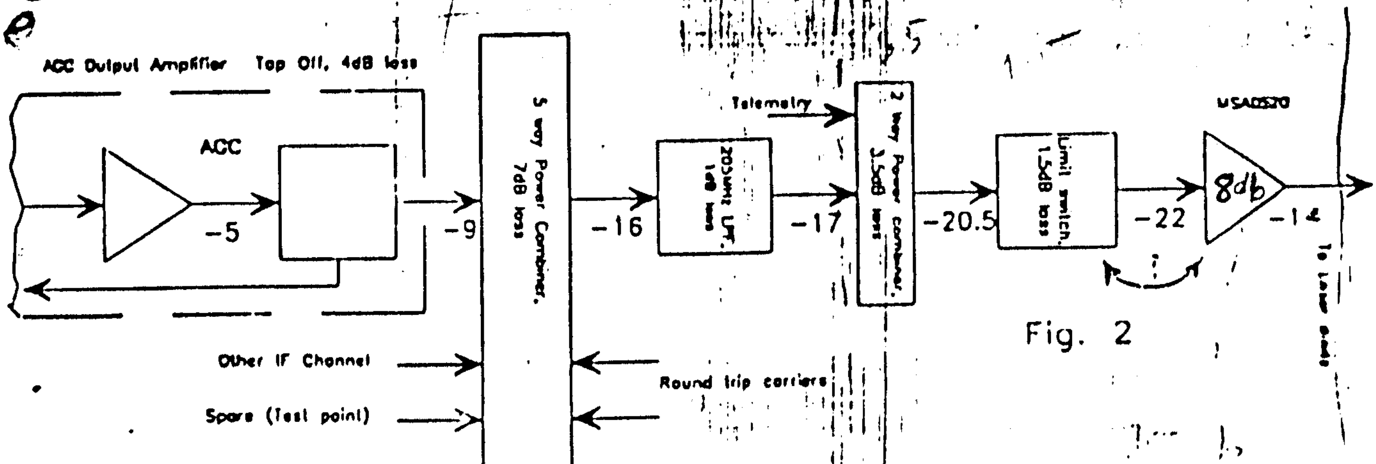
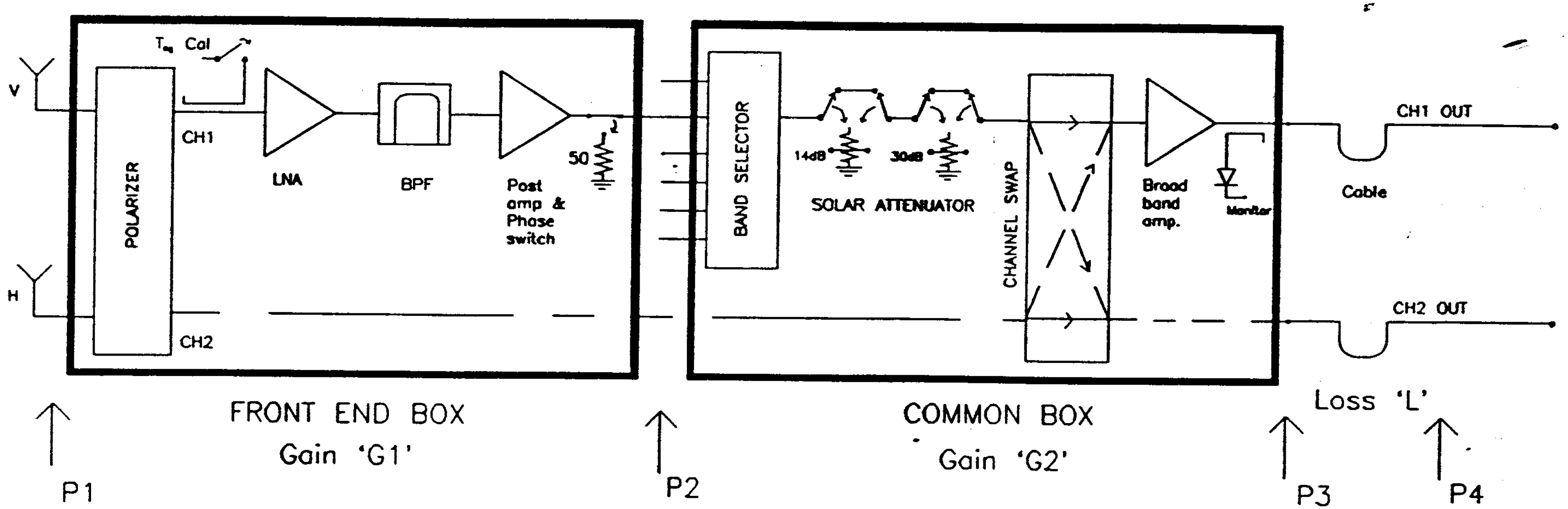


Fig. 2

Fig. 2.

Minuted by K.S.Saini

RF FRONT-END LEVEL DIAGRAM [32 MHz BW]



FREQ. BAND [MHz]	T_{sys} [K]	P1 [dBm]	G1 [dB]	P2 [dBm]	G2 [dB]	P3 [dBm]	L [dB]	P4 [dBm]
150	580	−96	34	−62	28	−34	8	−42
233	234	−100	37	−63	27	−36	9	−45
327	108	−103	38	−65	27	−38	11	−49
610	101	−104	35	−69	26	−43	15	−58
1060	83	−104	50	−54	25	−29	22	−51
1170	77	−105	49	−56	24	−32	23	−55
1280	74	−105	49	−56	23	−33	24	−57
1390	72	−105	47	−58	23	−35	26	−61

Note: Power levels are over 32 MHz BW; with 0dB solar attn.

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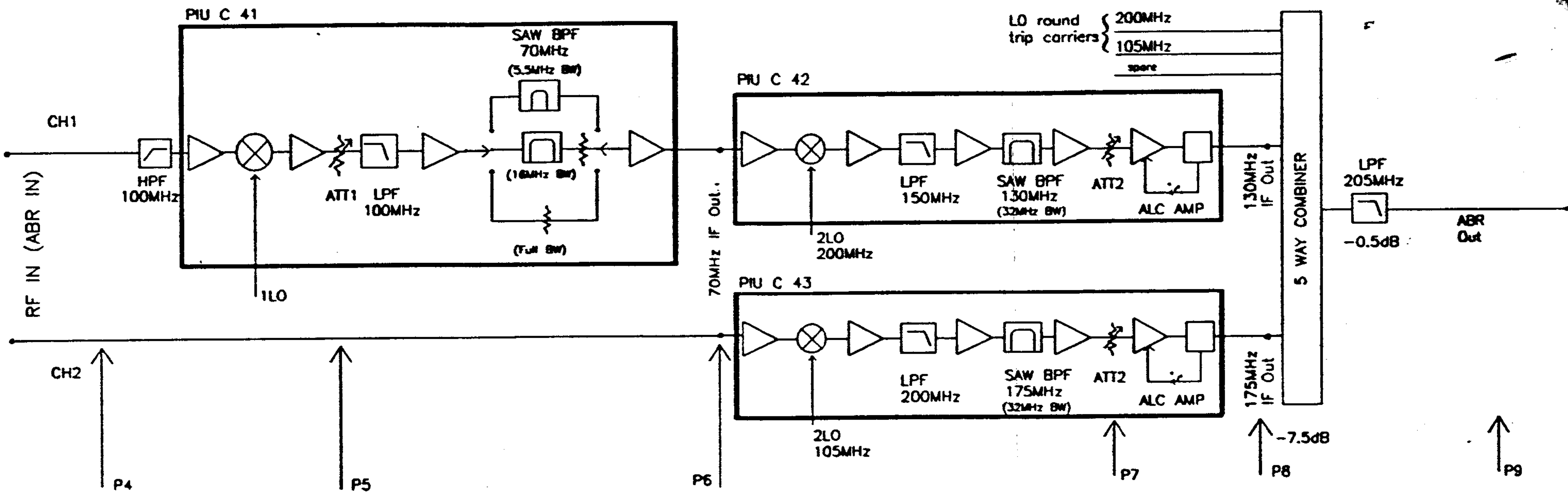
ANNEXURE - B. 2.

ANTENNA BASE RECEIVER LEVEL DIAGRAM



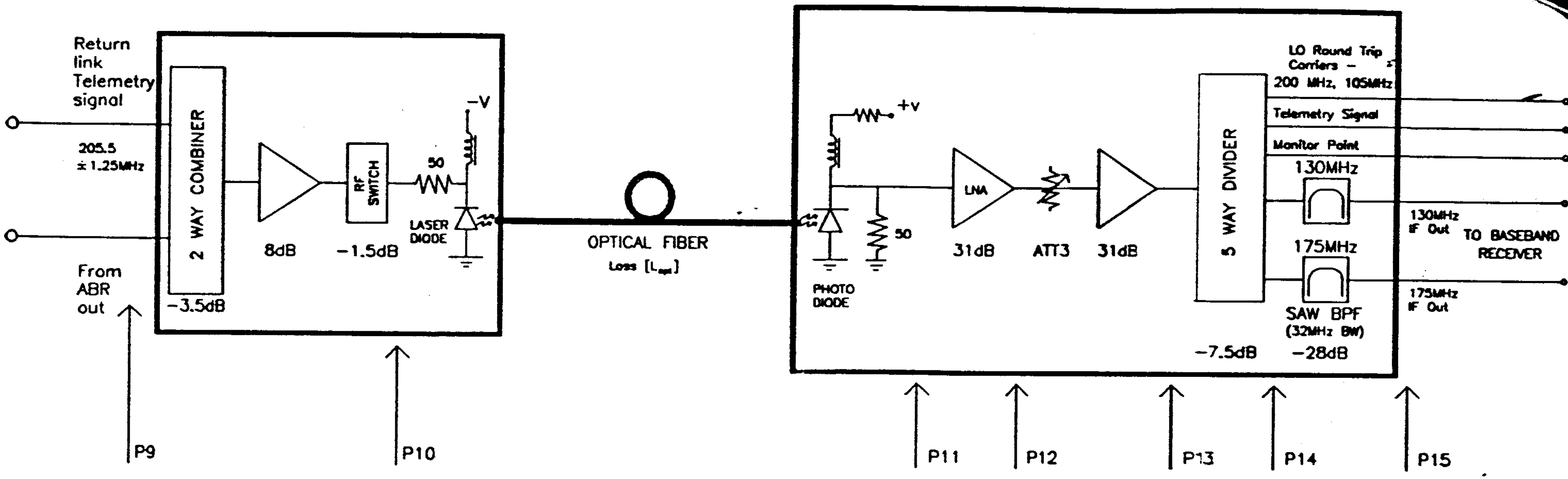
FREQ. BAND [MHz]	P4 [dBm/32MHz]	P5 [dBm/32MHz]	ATT1 [dB]	P6 [dBm]	P7 [dBm]	ATT2* [dB]	P8 [dBm]	P9 [dBm]
150	−42	−17	18	−34	−17	16	−12	
233	−45	−20	16	−35	−18	16	−12	−20 in each channel or −17 total power
327	−49	−24	12	−35	−18	16	−12	
610	−58	−34	10	−43	−26	8	−12	
1060	−51	−28	10	−37	−20	14	−12	
1170	−55	−33	10	−42	−25	8	−12	
1280	−57	−35	10	−44	−27	6	−12	
1390	−61	−40	8	−47	−30	4	−12	

Note: 1. Attenuation for ALC mode: (For Non-ALC mode operation add 6dB more attenuator to get −12dBm @ P8.)

2. Channels 16 & 20 of MCM #9 should read 131 (±5) counts, to indicate proper ALC setting. For quick check, adding 4dB more attn. in the above setting will cause the MCM channels (16 & 20) counts to read 215 (±5) ,showing that operating point is just under for AGC.

[redacted]

FIBER-OPTIC LINK LEVEL DIAGRAM



P9 [dBm]	P10 [dBm]	L_{opt} [dB]	P11 [dBm]	P12 [dBm]	ATT3 [dB]	P13 [dBm]	P14 [dBm]	P15 [dBm]
-17 [-20 per ch.]	-14 [-17 per ch.]	0	-50	-19	22	-10	-17.5 [-20.5 per ch.]	~-49 @ 130MHz & 175MHz Outputs
		5	-60	-29	12			
		10	-70	-39	2			
		11	-72	-41	0			

Note: 1. 0dB Nett gain in the optical fiber link means P9 to P14 gain is 0dB.
2. 0dB Nett gain can be assured only upto optical loss of 11dB.

ANNEXURE - B.3.

ANNEXURE - C-1

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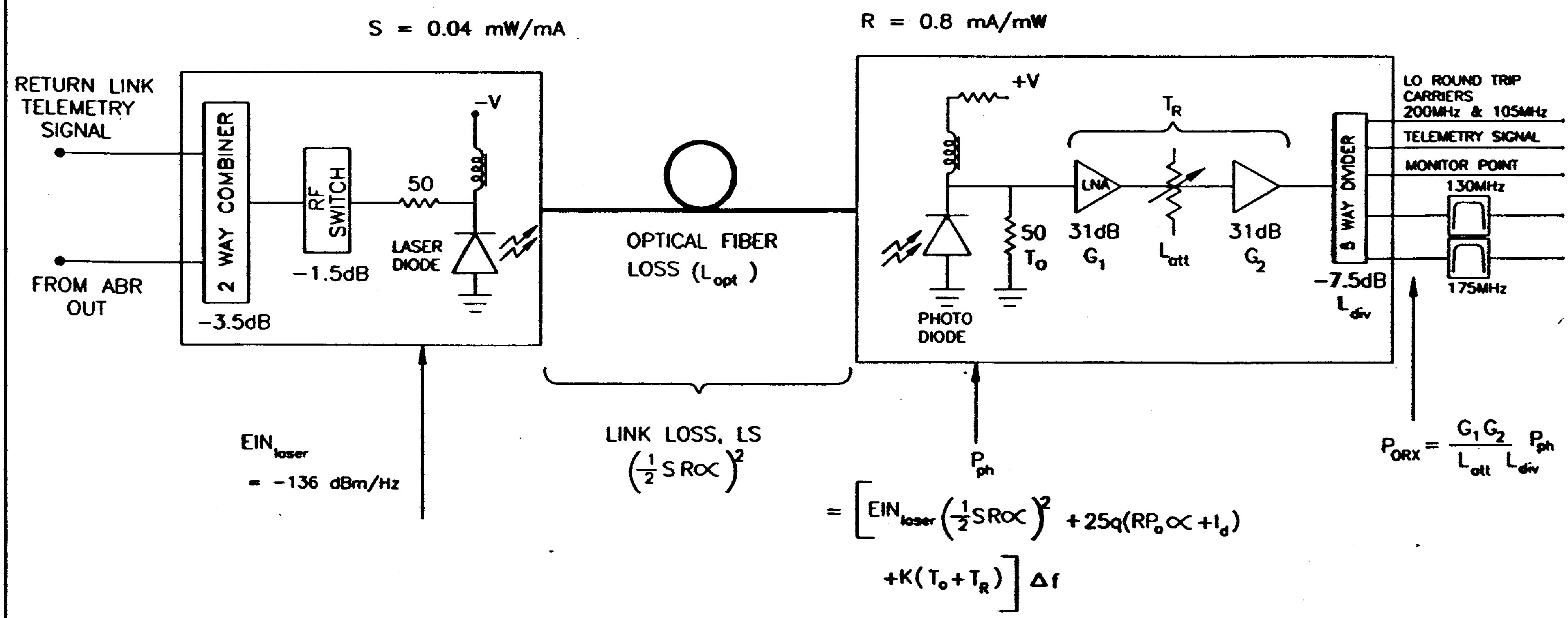
GMRT FIBER — OPTIC RETURN LINK



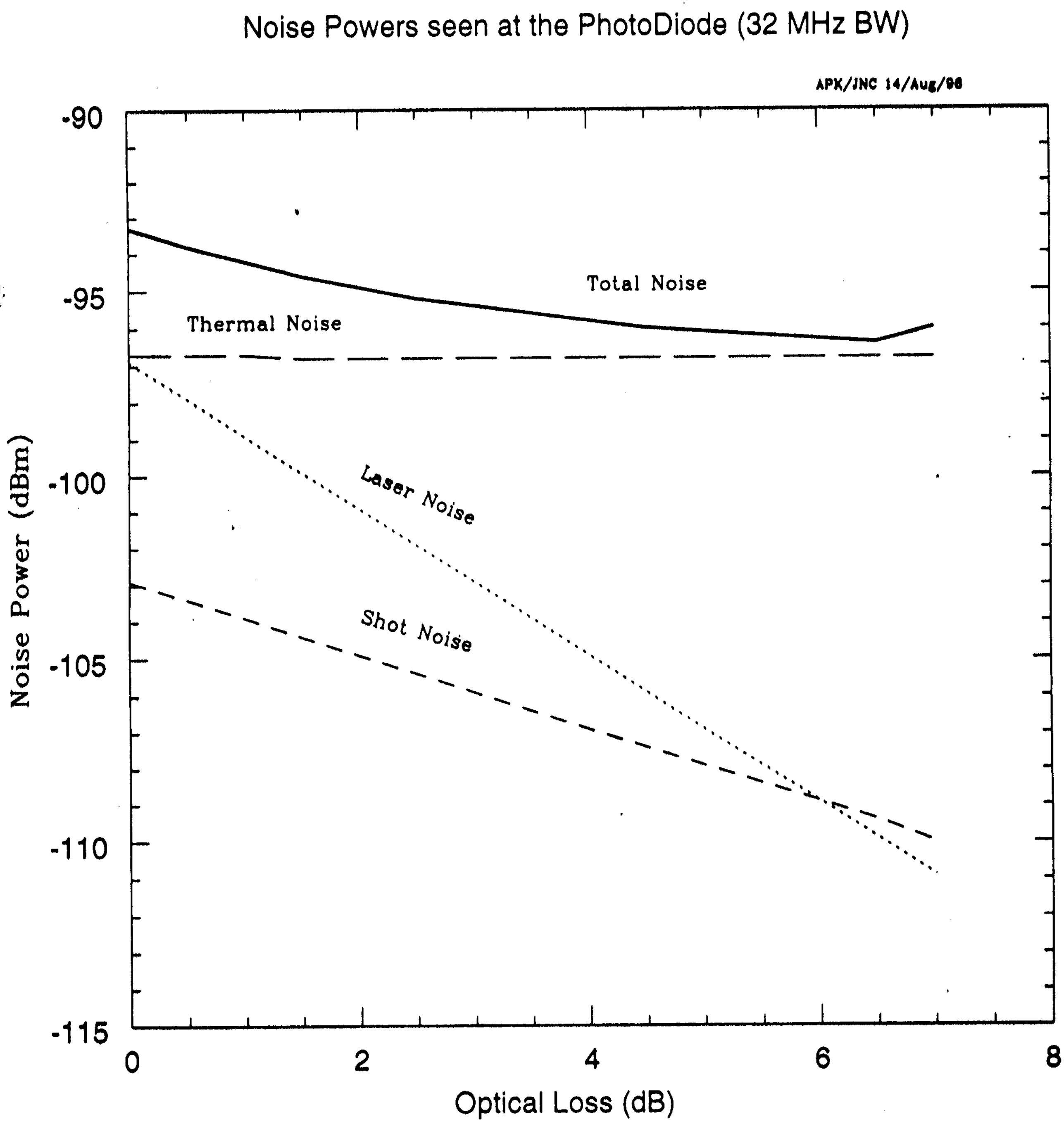
ANNEXURE C-2

GMRT FIBER – OPTIC RETURN LINK
SYSTEM NOISE LEVELS

APK/VD/SS
26/06/96

EIN_{laser}, LASER EQUIVALENT INPUT NOISE = −136dBm/Hz (=2.5×10^{-17} W/Hz)	q , ELECTRONIC CHARGE = 1.6×10^{-19} COULOMBS
S, SLOPE RESPONSIVITY OF LASER DIODE = 0.04 mW/mA	P_o , Av.OPTICAL POWER = 0.5 mW
R, RESPONSIVITY OF PHOTODIODE = 0.8 mA/mW	I_d , PHOTO DIODE DARK CURRENT = 5nA
L_{opt} = OPTICAL LOSS	T_o , AMBIENT TEMPERATURE = 300°K
Δf, BAND WIDTH = 32 MHz	$\alpha = 1/L_{opt}$
ORX = FIBER-OPTIC RECEIVER	

L_{opt} dB	α	L_{att} dB	LINK ELEC. LOSS $(\frac{1}{2}SR\alpha)^2$ dB	$T_R = 175 + \frac{(L_{att}-1)300}{1259} + \frac{175\times L_{att}}{1259}$ °K	NOISE LEVELS SEEN AT PHOTODIODE OUTPUT (32 MHz B.W): LASER NOISE $P_{n\,laser} = EIN_{laser}(\frac{1}{2}SR\alpha)^2\Delta f$ 10^{-13} W	LASER NOISE dBm	SHOT NOISE $P_{sh} = 2q(RP_o\alpha + I_d)\Delta f$ 10^{-13} W	SHOT NOISE dBm	THERMAL NOISE $P_{th} = K(T_O + T_R)\Delta f$ 10^{-13} W	THERMAL NOISE dBm	TOTAL NOISE POWER $P_{Ph} = P_{n\,laser} + P_{sh} + P_{th}$ 10^{-13} W	TOTAL NOISE POWER dBm	TOTAL NOISE AT ORX MONITOR POINT (32 MHz) $P_{ORX} = \frac{G_1G_2}{L_{att}L_{div}} P_{ph}$ 10^{-6} W	TOTAL NOISE AT ORX dBm
0	1	14	−36	184	2.048	−96.9	0.512	−102.90	2.13	−96.7	4.69	−93.3	5.26	−52.8
0.5	0.89	13	−37	182	1.622	−97.9	0.455	−103.41	2.13	−96.7	4.21	−93.8	5.94	−52.3
1	0.794	12	−38	181	1.290	−98.9	0.406	−103.91	2.123	−96.7	3.82	−94.2	6.79	−51.7
1.5	0.707	11	−39	180	1.027	−99.9	0.343	−104.42	2.11	−96.8	3.48	−94.6	7.79	−51.1
2	0.631	10	−40	179	0.812	−100.9	0.322	−104.92	2.11	−96.8	3.25	−94.9	9.16	−50.4
2.5	0.562	9	−41	178	0.645	−101.9	0.288	−105.41	2.1	−96.8	3.03	−95.2	10.76	−49.7
3	0.501	8	−42	177	0.512	−102.9	0.256	−105.91	2.1	−96.8	2.875	−95.4	12.9	−48.9
3.5	0.446	7	−43	177	0.409	−103.9	0.229	−106.40	2.1	−96.8	2.74	−95.6	15.42	−48.1
4	0.398	6	−44	176	0.324	−104.9	0.204	−106.90	2.1	−96.8	2.63	−95.8	18.62	−47.3
4.5	0.355	5	−45	176	0.259	−105.9	0.182	−107.40	2.1	−96.8	2.54	−96.0	22.65	−46.5
5	0.316	4	−46	176	0.205	−106.9	0.162	−107.90	2.1	−96.8	2.47	−96.1	27.04	−45.7
5.5	0.281	3	−47	176	0.162	−107.9	0.144	−108.40	2.09	−96.8	2.41	−96.2	33.88	−44.7
6	0.251	2	−48	175	0.129	−108.9	0.138	−108.91	2.09	−96.8	2.36	−96.3	41.98	−43.8
6.5	0.223	1	−49	175	0.103	−109.9	0.115	−109.40	2.09	−96.8	2.32	−96.4	51.88	−42.8
7	0.199	0	−50	175	0.082	−110.9	0.102	−110.00	2.09	−96.8	2.29	−96.4	64.57	−41.9



Noise Powers seen at the PhotoDiode (32 MHz BW)
APK/JNC 14/Aug/96
-90
-95
-100
-105
-110
-115
Noise Power (dBm)
Total Noise
Thermal Noise
Laser Noise
Shot Noise
0
2
4
6
8
Optical Loss (dB)

ANNEXURE C-3

APK
8/7/96

GMRT FIBER — OPTIC RETURN LINK
EQUIVALENT SYSTEM NOISE TEMPERATURES

L_s = LINK ELECTRICAL LOSS $\left(\frac{1}{2} S R \alpha\right)^2$

L_{opt} = OPTICAL LOSS

q = ELECTRONIC CHARGE = 1.6×10^{-19} COULOMBS

P_0 = AVG. OPTICAL POWER = 0.5mW

I_d = PHOTODIODE DARK CURRENT = 5nA

α = OPTICAL TRANSMISSION FACTOR = $1/L_{opt}$

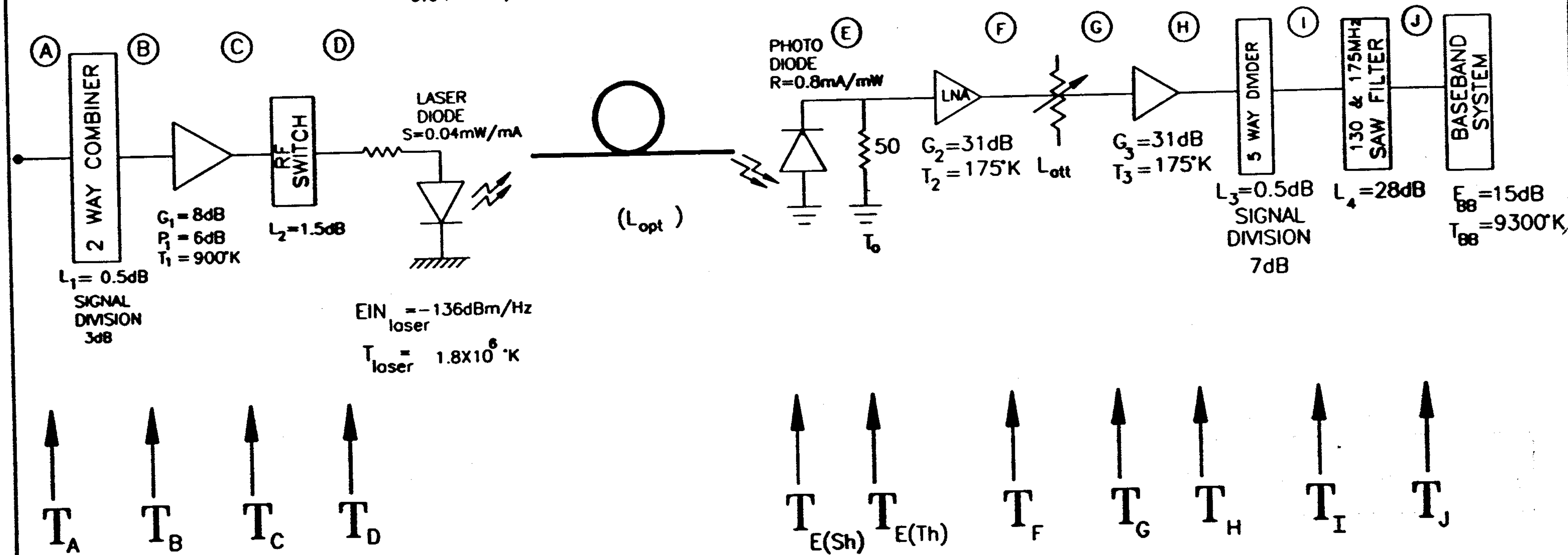
S = SLOPE RESPONSIVITY OF LASER 0.04 mW/mA

T_0 = AMBIENT TEMP. = 300°K

$T_{E(sh)}$ = THERMAL NOISE TEMP. AT (E)

$T_{E(th)}$ = SHOT NOISE TEMP. OF PHOTODIODE AT (E)

R = RESPONSIVITY OF PHOTODIODE 0.8 mA/mW



ANNEXURE C-4

APK
08/07/96

GMRT FIBER – OPTIC RETURN LINK
EQUIVALENT SYSTEM NOISE TEMPERATURES

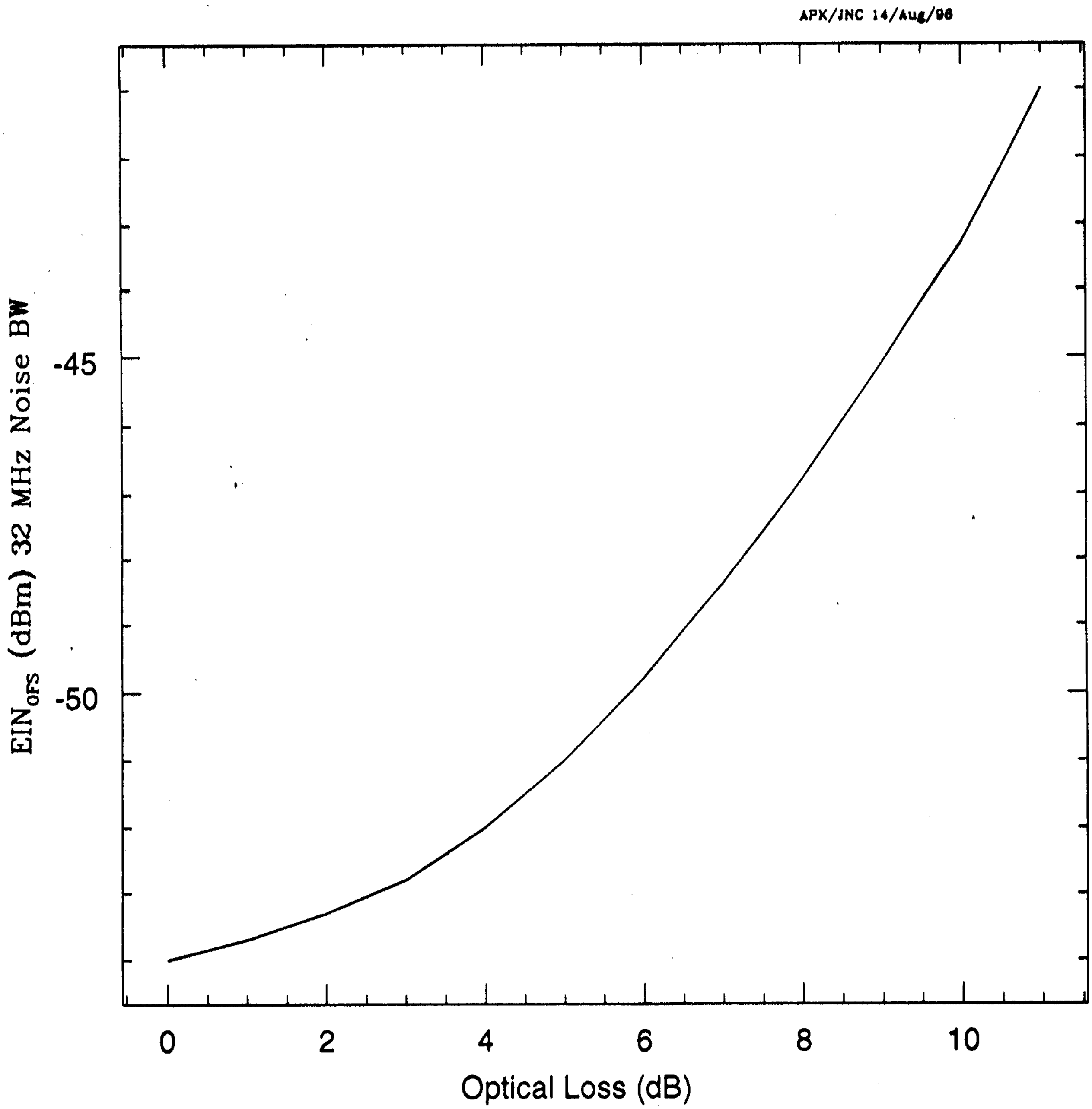
EIN_{OFS} (32MHz) dBm	T_A $\times 10^6$ °K	T_B $\times 10^6$ °K	T_C $\times 10^6$ °K	T_D $\times 10^6$ °K	L_S dB	L_{opt} dB	T_{ORX} °K	$T_{E(sh)}$ °K	$T_{E(th)}$ °K	T_F $\times 10^4$ °K	L_{att} dB	T_G °K	T_H °K	T_I °K	T_J °K
−54.0	9.00	4.02	25.38	17.97	−36	0	4062	116	3946	437	22	T_G = 27182°K	$T_H = 34 \times 10^6$ °K	T_I = 6057300°K	T_J = 9300°K
−53.7	9.61	4.29	27.06	19.16	−38	1	2751	92	2659	275	20				
−53.3	10.55	4.71	29.69	21.02	−40	2	1922	73	1849	173	18				
−52.8	12.07	5.39	34.04	24.10	−42	3	1407	58	1349	110	16				
−52.0	14.36	6.41	40.47	28.65	−44	4	1069	46	1023	68.6	14				
−51.0	18.10	8.08	50.96	36.08	−46	5	861	37	824	43.9	12				
−49.8	23.74	10.60	66.90	47.36	−48	6	722	29	693	27.5	10				
−48.4	32.44	14.48	91.39	64.70	−50	7	629	23	606	16.5	8				
−46.8	46.99	20.98	132.38	93.72	−52	8	580	18	562	11.0	6				
−45.1	70.76	31.59	199.32	141.11	−54	9	554.6	14.6	540	8.2	4				
−43.3	106.74	47.65	300.62	212.82	−56	10	530.1	11.6	518	5.5	2				
−41.5	160.94	71.85	453.34	320.94	−58	11	505.8	9.2	497	2.7	0				

WHERE

$T_A = T_{OFS} = 2.24 T_B + (L_1 - 1) T_0$	$T_B = \frac{T_C}{G_1} + T_1 \approx T_C/G_1$	$T_C = L_2 T_D + (L_2 - 1) T_0 \approx L_2 T_D$	$T_D = L_S T_{ORX} + T_{laser}$	$T_{ORX} = T_{E(th)} + T_{E(sh)}$	$T_{E(th)} = T_0 + T_2 + \frac{T_F}{G_2}$

$T_{E(sh)} = \frac{25q(RP_0\alpha + T_0)}{K}$	$T_F = L_{att} T_G + (L_{att} - 1) T_0$	$T_G = \frac{T_H}{G_3} + T_3$	$T_H = 5.6 T_I + (L_3 - 1) T_0$	$T_I = L_4 T_{BB} + (L_4 - 1) T_0$	$T_J = T_{BB}$	$L_S = (\frac{1}{2} S R \alpha)^2$

EIN of Fiber-Optic Link as a function of Optical Loss



Annexure D

Comparison of System Noise and Operating Levels

(Refer figure in Annexure C-3)

	No Amplifier		G_1=8 dB Amplifier		G_1=12 dB Amplifier*	
Optical Loss (dB)	EIN_{OF-BB} [Δf=32 MHz] (dbm)	ABR Output Level required to maintain 20dB S/N (dbm)	EIN_{OF-BB} [Δf=32 MHz] (dbm)	ABR Output Level required to maintain 20 dB S/N (dbm)	EIN_{OF-BB} [Δf=32 MHz] (dbm)	ABR Output Level required to maintain 20 dB S/N (dbm)
0	-46.0	-26.0	-54.0	-34.0	-58.0	-38.0
1	-45.7	-25.7	-53.7	-33.7	-57.7	-37.7
2	-45.3	-25.3	-53.3	-33.3	-57.3	-37.3
3	-44.7	-24.7	-52.8	-32.8	-56.7	-36.7
4	-44.0	-24.0	-52.0	-32.0	-56.0	-36.0
5	-43.0	-23.0	-51.0	-31.0	-55.0	-35.0
6	-41.8	-21.8	-49.8	-29.8	-53.8	-33.8
7	-40.4	-20.4	-48.4	-28.4	-52.4	-32.4
8	-38.8	-18.8	-46.8	-26.8	-50.8	-30.8
9	-37.0	-17.0	-45.1	-25.1	-49.0	-29.0
10	-35.3	-15.3	-43.3	-23.3	-47.3	-27.3
11	-33.5	-13.5	-41.5	-21.5	-45.5	-25.5

* **With G_1=12 dB, Fiber-optic link is adjusted for 4 dB net gain.**