

EDC

Trend of Electronic Dispersion Compensation Technique for Optical Transmission

(S.U. Lee) TDM
(J.S. Ko) TDM

TF(Transversal Filter) DFE(Decision Feedback Equalizer) 가
10Gb/s 40Gb/s
가

I. ISI(intersymbol interference)

1
(signal(t)) (1) [1].

$$10Gb/s \quad 40Gb/s \quad s(t) \quad ? \quad (0 \leq k \leq 1) t_0 \quad DGD$$

$$signal(t) = ks\left(t - \frac{t_0}{2}\right) + (1-k)s\left(t + \frac{t_0}{2}\right) \quad (1)$$

가 (PMD)

II.

가 가
가

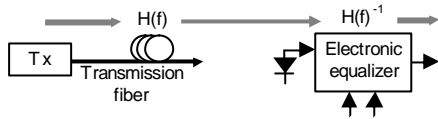
ISI

PMD 1

가 DGD(Differential Group Delay) 가
(,)

$H(f)^{-1}$ 가

(port,)
H(f)
 $H_{comp}(f)$
가



(1)

가
$$[2]. \quad \frac{H(f) \times H(f)^{-1}}{H(f)^{-1}} = 1$$
 가

((1)).

1.

(transversal filter)

. (2) N (tap) [3].

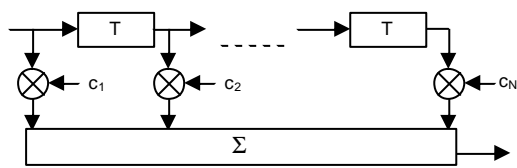
(T) () () . ISI가

c_i 가 가 $y(t)$ (2) 가

$$y(t) = \sum_{j=1}^N c_j n(t - (j-1)T) \quad (2)$$

$v(t)$ 가 $H_{comp}(f)$ 가

가 LMS(Least - Mean-Square) 가 (3)



(2) 가

[4].

$$c_j^{k+1} = c_j^k + \Delta e_k n_{k-j}, \quad k = 1, 2, \dots, j = 1, 2, \dots, N \quad (3)$$

c_j^k k j 가

, Δ 가

, v_k k

, ϵ_k (4)

y_k .

$$e_k = I_k - y_k \quad (4)$$

I_k k

2.

DFE(Decision Feedback Equalizer)

. (3)

[2].

DFE 가

B_i

가 DFE

'1' '0'

ISI

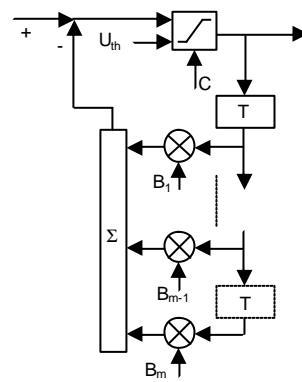
(gate),

, 가

가

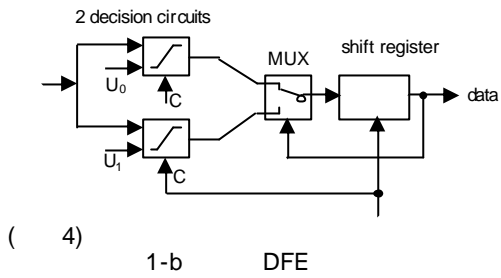
(loop)

DFE



(3)

DFE



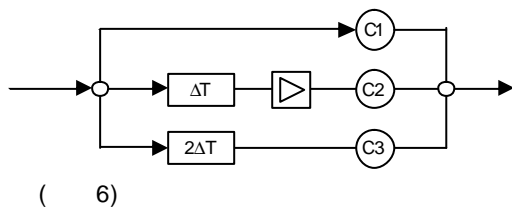
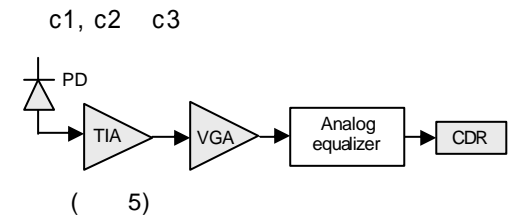
DFE ((4))
 [5]. 1 (bit shift) DFE

III.

1.

(5) 가 TIA (transimpedance amplifier), VGA(Variable Gain Amplifier) CDR(Clock and Data Recovery)

[1]. Schlump (6) PMD , 가 가

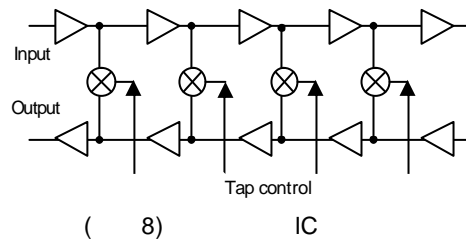
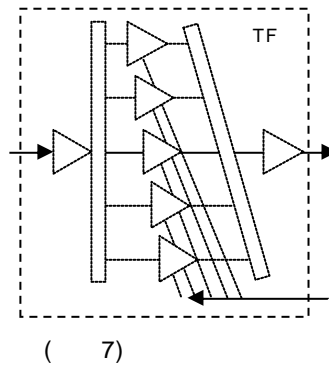


Frazer 가 (7)
 (TF)
 [7]. 5

가 50ps (50ps)
 가) 5

가 40dB
 0 180
 10Gb/s (8)
 [8]. 1 가

가 -1 1
 3dB 15.5GHz

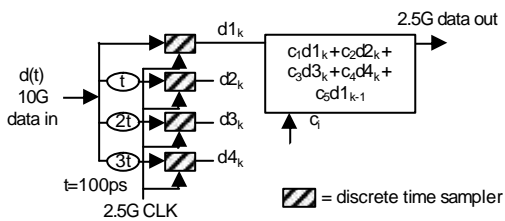


Buelow 가
 7 55ps 가 8 가 [9]. (10) ,
 가 가 (mixer), 가 (adder)
 10Gb/s 가 가 " -1" "1"
 Buelow 4 T_{d1} T_{d2}
 IC [10]. 가 가
 IC 가 가
 -1 +1 IC PMD
 70ps 12GHz 20ps DGD

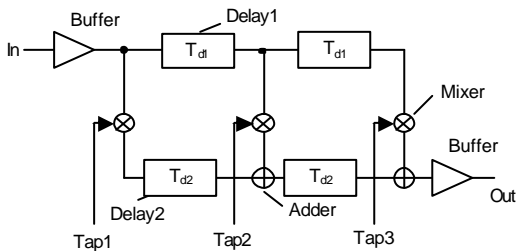
Woodward (9)
 5 [11].
 (impulse)
 (c_n)

10Gb/s
 4 1 4

Nakamura 40Gb/s
 [12].



(9) (pipeline) TF

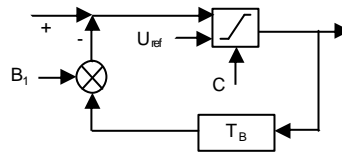


(10)

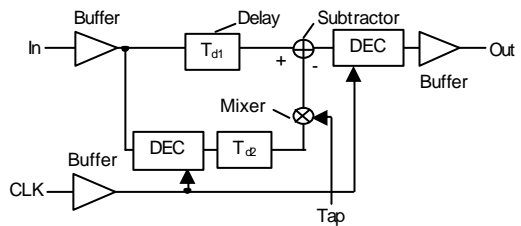
2.
 Buelow (11)
 DFE [9]. DFE
 가 (B₁)
 (T_B=100ps)

DFE U_{ref}
 가 B₁

Nakamura 40Gb/s DFE [12].
 DFE (12)
 (feed-forward)
 DFE 가



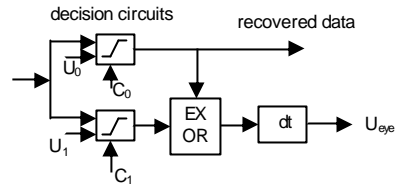
(11) DFE



(12) DFE

40Gb/s DFE

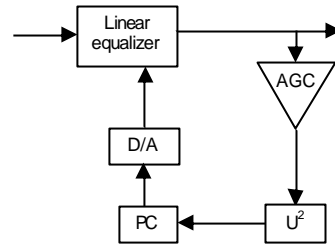
가



가

(13)

가



(14)

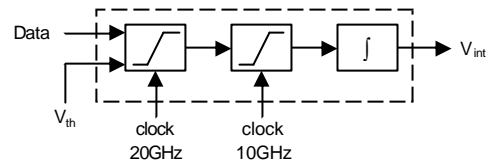
3.

PMD가 가

가

Buelow

(eye)



(15) 40Gb/s

13)

U0

U1

PMD

(Pseudorandom binary sequence) (pattern)

"0" "1" 가
 "1" "0"
 "0"/"1"
 "0" "1"

OR

EX-

"1/2"

가

가

4.

Buelow

(14)

Buelow

DFE

AGC

(TF+DFE)

IC

[9].

Buchali

[10].

40Gb/s

TF DFE 가

PMD

TF

(15)

Moeller

1 DFE

10Gb/s

120ps

DGD

ISI

[14]. 가

[15].

10Gb/s

"0" "1"

. PRBS

10Gb/s 80km 가
 20km 10Gb/s 40Gb/s
 [11].
 EAM(electroabsorption modulator)
 , 가
 . EAM LiNbO₃ 가
 DML(directly modulated distributed feedback laser) 가
 (metro) 2.5Gb/s
 . Feuer 10Gb/s
 DML
 [16].
 20km 가
 Kanter 가
 Mach-Zehnder EAM
 [17].
 40km 10Gb/s EAM 가
 50% 가
 10 가
 LAN SAN
 . 10Gb/s
 . Pepeljugoski
 850nm 7
 [18].
 50ps 10Gb/s
 ISI
 11dB 2.2dB

IV.

FEC(Forward Error Correction)

[1] K. Azadet et al., "Equalization and FEC Techniques for Optical Transceivers," IEEE Journal of Solid - State Circuits, Mar. 2002, pp.317-327.
 [2] F. Buchali and H. Buelow, "Adaptive PMD Compensation by Electrical and Optical Techniques," Journal of Lightwave Technology, Apr. 2004, pp.1116-1126.
 [3] J.H. Winters et al., "Reducing the Effects of Transmission Impairments in Digital Fiber Optic Systems," IEEE Communications Magazine, June 1993, pp.68-76.
 [4] J.H. Winters and R.D. Gitlin, "Electrical Signal Processing Techniques in Long -Haul Fiber -Optic Systems," IEEE Transactions on Communications, Sep. 1990, pp.1439-1453.
 [5] S. Kasturia and J.H. Winters, "Techniques for High-Speed Implementation of Nonlinear Cancellation," IEEE Journal on Selected Areas in Communications, June 1991, pp.711-717.
 [6] D. Schlump et al., "Electronic Equalization of PMD and Chromatic Dispersion Induced Distortion after 100km Standard Fibre at 10Gbit/s," ECOC 98, Madrid, Spain, 20-24 Sep. 1998, pp.535-536.
 [7] G.L. Frazer et al., "Static and Dynamic Performance of an Adaptive Receiver for 10Gbps Optical Transmission," ECOC 2000, pp.113-114.
 [8] B. Wedding et al., "SiGe Circuits for High Bit -rate Optical Transmission Systems," International Symposium on Circuits and Systems, Orlando, Vol.2, May 30, June 2, 1999, pp.492-495.
 [9] H. Buelow et al., "PMD Mitigation at 10Gbit/s Using Linear and Nonlinear Integrated Electronic Equaliser Circuits," Electronics Letters, 20 Jan. 2000, pp.163-164.
 [10] H. Buelow et al., "Adaptive PMD Mitigation at 10Gbit/s Using an Electronic SiGe Equalizer IC," ECOC'99, Nice France, 26-30 Sep. 1999, pp.38-139.
 [11] S.L. Woodward et al., "Demonstration of an Electronic Dispersion Compensator in a 100km 10Gb/s

-
- Ring Network," IEEE Photonics Technology Letters, June 2003, pp.867-869.
- [12] M. Nakamura et al., "Electrical PMD Equalizer ICs for a 40Gbit/s Transmission," OFC 2004, TuG4.
- [13] H. Buelow et al., "Adaptation of an Electronic PMD Mitigator by Maximization of the Eye Opening," ECOC 2000, pp.209-210.
- [14] F. Buchali et al., "A 40Gb/s Eye Monitor and Its Application to Adaptive PMD Compensation," OFC 2002, WE6, pp.202-203.
- [15] L. Moeller et al., "ISI Mitigation Using Decision Feedback Loop Demonstrated with PMD Distorted 10Gbit/s Signals," Electronics Letters, 25 Nov. 1999, pp.2092-2093.
- [16] M.D. Feuer et al., "Electronic Dispersion Compensation for a 10Gb/s Link Using a Directly Modulated Laser," IEEE Photonics Technology Letters, Dec. 2003, pp.1788-1790.
- [17] G.S. Kanter et al., "Electronic Equalization for Extending the Reach of Electro-Absorption Modulator Based Transponders," OFC 2003, ThG6.
- [18] P. Pepeljugoski et al., "Improved Performance of 10Gb/s Multimode Fiber Optic Links Using Equalization," OFC 2003, ThG4, pp.472-474.