Performance Analyses of Fiber-optic Wireless Communication Using Direct Detection

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Abstract— To realize high-speed over GHz bps, it is needed to reduce and suppress the pulse width because of dispersion effect in fiber. We analyzed the performance and waveform due to chirping effect in fiber.

Index Terms—Fiber-optic communication, Direct detection

I. Introduction

Optical communication is developed to construct high-speed multimedia information service. There are a variety of needs to obtain high quality service such as personalization, complication, and etc. To implement this kind of service, high-speed data, high quality image and narrow band service including audio and low speed data. It should be considered with efficiency. The most important to be used in signal transmission is that it provides numerous bandwidth and low loss in single mode fiber. The region, 1200~1700 nm, with low loss exceeds its optical bandwidth over 20THz. This makes long transmission without signal regeneration because of its low loss and numerous bandwidth. The optical analog transmission of GHz range signals is recently attracting much interest for WLL (Wireless Local Loop), CATV, and satellite system applications. In these applications, direct modulation of a semiconductor laser diode is used for transmitting signals multiplexed by RF range subcarriers. Consequently, the LD (Laser Diode) non-linearity becomes a key issue in the system performance because it can interfere and limit the number of channels as well as transmission distance [1-5].

II. Optical Communication Technology

Optical communication is useful for wire communication media. It can be reliable and economic technology in these days. A fiber-optic wireless uplink system can be classified as baseband, microwave IF subcarrier and radio frequency subcarrier according to subcarrier frequencies of signals transmitted in an optical fiber link. In the baseband transmission, influence of the fiber dispersion effect is negligible, and the base station configuration is the most complex. To use this method without a subcarrier frequency, we can construct fiber optic wireless communication configuration. The combination of fiber optic and wireless techniques offers advantages for picocell broadband mobile communication systems. Additionally to the low-loss transmission and large bandwidth of the fibers, the remote generation of the high-speed signals is a powerful advantage of the optical technique.

2.1. Construction of broadband communication network

A basic configuration is shown in Fig. 2-1. It consists of wireless-wave link by using fiber-optic to deliver tens of GHz wave signal transmission technique. Data transmitted in central station through tens of GHz wave link is transmitted into base station by using fiber-optic link. And, it spreads out by wireless data through the antenna in base station. A fiber-optic wireless wave system can be classified as baseband, IF subcarrier and GHz wave radio frequency subcarrier. We briefly explain its method as follows. In baseband, a signal in control station transmitted into base station through fiber link. Then, signal turn optical signal into electrical signal.

In an Intensity Modulation Direct Detection link, the tens of GHz wave signal is carried as a lower and upper side band on the optical carrier. Due to the dispersion and the large frequency offset between the side bands and the optical carrier, the phase of each of the spectral components of the transmitted optical signal has experienced a differential change. After detection, this results in a power reduction of the recovered GHz signal and thereby decreasing its carrier to noise ratio (CNR)[6-7].

III. Simulation Model

3.1 Configuration of system

We have analyzed the performance of system that merges with wireless and optical communication by direct detection technique in this paper. Figure 1 shows the configuration of system. Table 1 shows the parameters used in simulation. We obtained the results of outputs of component from computer simulation considering chirping of laser diode and effect of dispersion in fiber.

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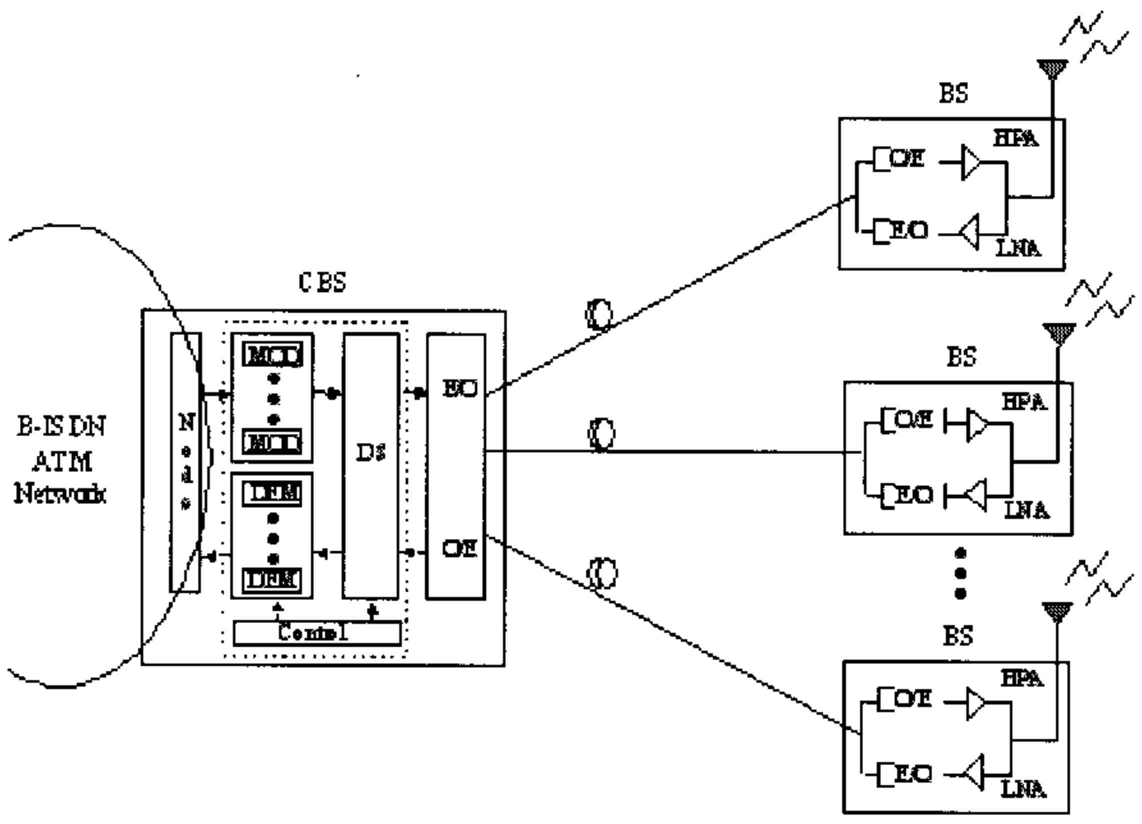


Fig. 1 Configuration of fiber-optic wireless communication network

Table 1. Parameters used in simulation

Notation	Definition	Value
Γ	mode confinement factor	0.4
n0	electron density at transparency	1018 cm-3
τ p	photon lifetime	3 ps
τ n	electron lifetime	1 ns
β	spontaneous emission factor	3 x 10-5
q	electron charge	1.6x10-19 C
Va	active voulume	1.5x10-10 cm3
α	linewidth enhancement factor	5
vg	group velocity	8.5x109 cm/s
a0	gain coefficient	2.5x10-16 cm2
η 0	total quantum efficiency	0.4
ε	gain suppression factor	10-17 cm3
η	photodetector quantum efficiency	0.8
λ 0	dark current	6.25x1010/s
D	fiber dispersion constant	-17 ps/km/nm

3.2 Simulation model

The numerical model for the semiconductor lasers based on the typical Lang's equation has been extended in order to take into account the simultaneous injection of the multiple sidebands of the directly modulated master laser. The numerical simulations have showed that the unselected sidebands can affect the optical and RF-spectral characteristics even when the semiconductor laser is stable-locked to the target sidebands. The waveform of input signal is injected OOK(On-Off Keying) type to laser diode, we can obtain the results by solving rare equation of laser diode as follows.[6]

$$\frac{dp(t)}{dt} = \Gamma G(t)(n(t)-n_0)p(t) - \frac{p(t)}{\tau_p} + \frac{\beta\Gamma n(t)}{\tau_n} \quad (1)$$

$$\frac{dn(t)}{dt} = \frac{I_p(t)}{qV_a} - G(t)(n(t)-n_0)p(t) - \frac{n(t)}{\tau_p} \quad (2)$$

$$\frac{d\varphi(t)}{dt} = \frac{\alpha}{2}(\Gamma v_g a_0(n(t)-n_0) - \frac{1}{\tau_p} \quad (3)$$

$$G(t) = \frac{v_g a_0}{1+\varepsilon p(t)} \quad (4)$$

Where the parameters used in simulation shows in table 1. G(t) defines saturable gain coefficient value. The waveform of NRZ current generated in laser diode can be obtained by values between previous bit and current bit following equations.

$$I_P(t) = \begin{cases} I_{bias} + I_m(1-e^{(-2.2t/\tau_r)}) & \text{if } current=1, \text{ previous } bit=0 \\ I_{bias} + I_m e^{(-2.2t/\tau_r)} & \text{if } current=0, \text{ previous } bit=1 \\ I_{bias} & \text{if } current=0, \text{ previous } bit=0 \\ I_{bias} + I_m & \text{if } current=1, \text{ previous } bit=1 \end{cases} \quad (5)$$

Optical output value of laser diode can be obtained following equations.

$$p(t) = \frac{p(t)}{2}\frac{V_a \eta_0 h\nu}{\Gamma\tau_p} \quad (6)$$

Δ(t) depicts frequency of instantaneous chirp. η0 is differential quantum efficiency of laser diode.

$$\Delta\nu(t) = \frac{1}{2\pi}\frac{d\varphi(t)}{dt} \quad (7)$$

The equation can be summarized as follows.

$$\Delta\nu(t) = \left\{\frac{1}{p(t)}\frac{dp(t)}{dt} + \left[\frac{\varepsilon}{\tau_p} - \frac{\beta\Gamma n(t)}{\tau_n p(t)}\right]\right\} \quad (8)$$

First term is transient chirp and second term is adiabatic chirp. When dispersive single mode fiber takes into account, the equation can be obtained by electric field in output of fiber in frequency domain.

$$S_{fiber}(f) = H_{fiber}(f)S_s(f) \quad (9)$$

Where Hfiber(f) depicts transfer function of fiber. The output of fiber can be obtained using equivalent baseband transfer function of single mode fiber.

$$S_s(f) = \int_{t=\infty}^{\infty}\sqrt{p(t)}\,e^{j\varphi(t)}e^{-j2\pi t}\,dt \quad (10)$$

Where τ is distance of fiber, λ is wavelength, and c is velocity of light. The received current in receiver can be obtained as following equation.

$$i(t) = \frac{\eta\lambda}{hc}P_{FT}(t) + \lambda_0 \quad (11)$$

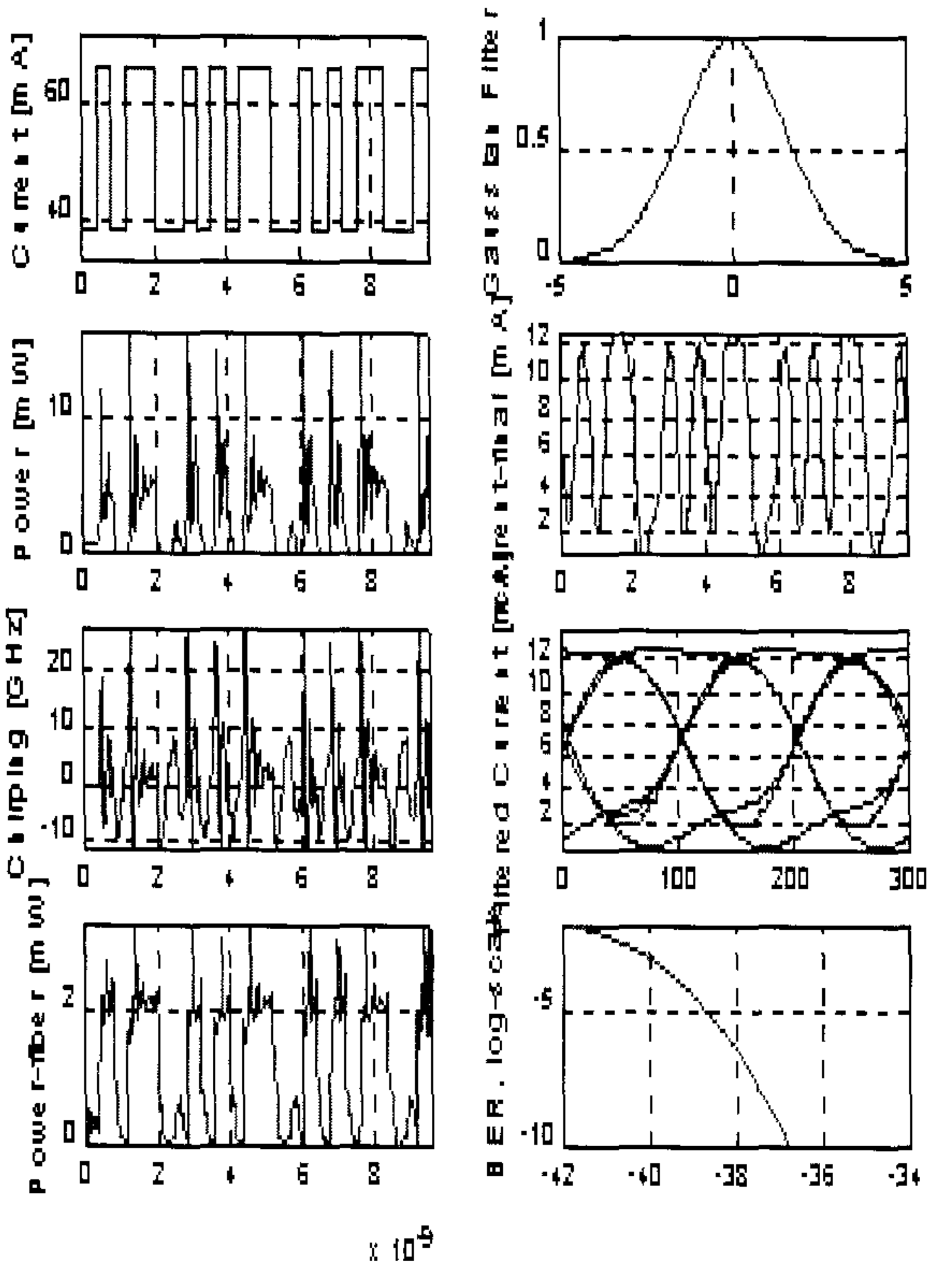
η is quantum efficient of photo diode, λ0 is dark current. PFP(t) can be calculated following equation.

$$P_{FP}(t) = s_{FP}(t)s^*{}_{FP}(t) \quad (12)$$

Received current received signal with Gaussian shaped frequency response characteristics.

$$H_R(F) = e^{-\pi\left(\frac{f}{2\pi R}\right)^2} \quad (13)$$

Where fR=0.75/T, and T is period of bit. The filter is used to minimize noise in receiver to maximize eye opening. Figure 2 shows the result of simulation. 18 bits of binary code are injected into laser diode with OOK data, laser diode output has chirping effect in waveform. The output power can be calculated by electric field through fiber. The final current can be obtained into photo diode with Gaussian filter. In photo diode, optical signal converted into electrical signal. BER test is required to measure the performance of system. We estimate the eye opening to measure the error of system.



(a) Waveform of transmitter (b) Waveform of Gaussian filter (C) Waveform of LD output (d) Waveform of Receiver (e) Waveform of output with chirping (f) Eye opening (g) Waveform of receiver through fiber (h) Waveform of BER

Fig. 2 Simulation Results

IV. Conclusions

Since a laser diode and photodiode are required for the optical feeder link between the control station and the base station, the wireless wave signal can be optically generated, offering a variety of advantages, including a cost reduction due to low speed oscillators and modulators necessary in the numerous base stations.
The combination of fiber optic and wireless wave techniques offers advantages for picocell broadband mobile communication systems. Additionally to the low-loss transmission and large bandwidth of the fibers is needed. We analyzed the performance of fiber-optic system.

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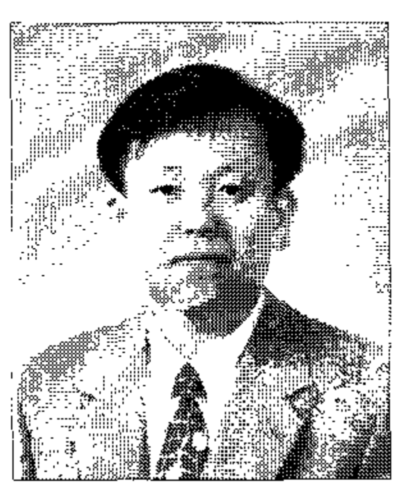

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He received his B.S. degree in Electronic Engineering from Yeungnam University in 1989 and M.S. and Ph.D. degrees in Electrical and Electronic Engineering from the Yonsei University in 1991 and 2001, respectively. From 1991 to 1996, he joined at ETRI, where he worked as Senior Member of Technical Staff. In 2002, he joined the department of Electronic Engineering, Mokwon University, Korea, where he is presently professor. His research interest is in the area of Information security system technology that includes Network security system design, Quantum cryptosystem, ASIC design of cryptosystem and Wireless communication.