Modeling the Impact of Group Velocity Dispersion on the Performance of 2-D WH/TS OCDMA Systems

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Abstract—**In this paper, a novel model of Gaussian pulse propagation in optical fiber is proposed to comprehensively analyze the impact of Group Velocity Dispersion (GVD) on the performance of two-dimensional wavelength hopping/time spreading optical code division multiple access (2-D WH/TS OCDMA) systems. In addition, many noise and interferences, including multiple access interference (MAI), optical beating interference (OBI), and receiver's noise are included in the analysis. Besides, we propose to use the heterodyne detection receiver so that the receiver's sensitivity can be improved. Analytical results show that, under the impact of GVD, the number of supportable users is extremely decreased and the maximum transmission length is remarkably shortened when the normal single mode fiber is used. The main factor that limits the system performance is time skewing. In addition, we show how the impact of GVD is relieved by dispersion-shifted fiber. For example, a system with 32 × 1 Gbit/s users can achieve a maximum transmission length of 111 km when transmitted optical power per bit is -5 dBm.**

I. INTRODUCTION

Optical code division multiple access (OCDMA) is a promising technique for next generation optical access networks [1]. Two-dimension wavelength hopping/time spreading (2-D WH/TS) OCDMA system is one kind of OCDMA systems that uses 2-D coding approach [2]. The 2-D codes are spread in both the time and frequency domains simultaneously, hence achieve better code performance in terms of both cardinality and correlation properties in comparison with that of the one-dimension (1-D) counterparts.

In 2-D WH/TS OCDMA system, the chip rate, though much lower compared with that in the 1-D systems, is still high. In addition, optical chips are transmitted on different wavelengths. The system performance therefore will be affected by fiber dispersion caused by the difference of group velocities of different wavelengths, a phenomenon referred to as group velocity dispersion (GVD) [3]. The impact of GVD includes pulse broadening, peak power reduction, and time skewing, as shown in Fig. 1. Of these effects, the time skewing, the relative temporal shifting of optical pulses on difference wavelengths, is an exclusive phenomenon in OCDMA systems using multi-wavelength signal due to its decoding operation [4].

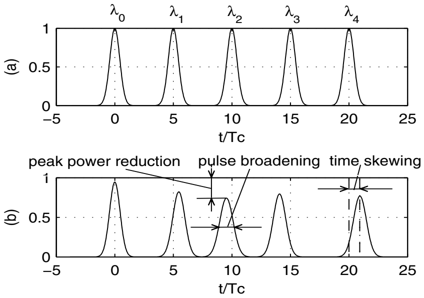

Fig. 1. Impact of GVD on multi-wavelength signal: (a) original chip sequence and (b) the chip sequence under the impact of GVD.

The first study on the impact of time skewing in the 2-D WH/TS OCDMA system was reported by Eddie K. H. Ng. et al. [4]. Based on coding theory the authors did an investigation the impact of temporal skewing on a code's auto- and cross-correlation properties. As well, they proposed methods for combating the deleterious effects of temporal skewing. In this work, however, the impact of pulse broadening and chip power reduction were not included. In addition, the analysis, which is purely based on coding theory without considering the impacts of any other noise and pulse propagation, is far from the real circumstances. Later, the impact of pulse broadening and time skewing were investigated separately by simulation [5]. The simulation results shown that time skewing effect strongly degrades the performance of the 2-D WH/TS OCDMA system. For 3-wavelength and 7-chip-time optimized code, it was shown that a 10-Gchip/s system is limited to under 4 kilometers. As this is a simulation work, the condition is, to some extent, inflexible, for example only three simultaneous users was assumed, and preset optimized codes was used.

In this paper, we therefore propose to use a realistic model of Gaussian pulse propagation in order to comprehensively analyze the impact of GVD on the performance of 2-D WH/TS OCDMA system. This model should be able to analyze all three effects of GVD, including pulse broadening, chip power reduction, and time skewing. Additionally, various noise and

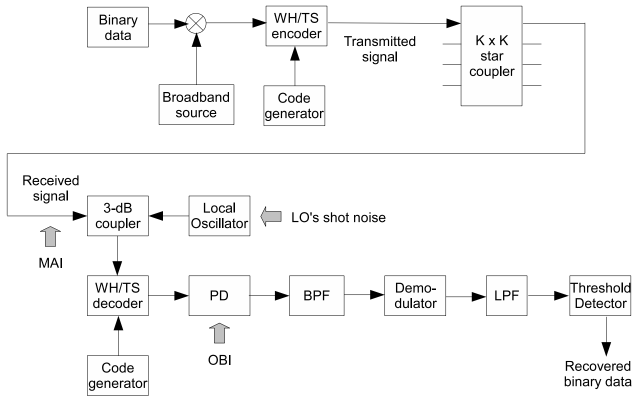

Fig. 2. Schematic diagram of a 2-D WH/TS OCDMA system using heterodyne detection receiver.

interferences, including multiple access interference (MAI), optical beating interference (OBI), and receiver's noise will be included in the analysis. Besides, we propose to use the heterodyne detection receiver so that the receiver's sensitivity can be improved and more users can be accommodated [6], [7]. As a matter of fact, under the impact of OBI, the 2-D WH/TS OCDMA system using direct detection receiver is severely degraded and apparently unable to accommodate more than 10 users [8].

The rest of the paper is organized as follows. Section II presents the descriptions of the 2-D WH/TS OCDMA system using heterodyne detection receiver. The performance analysis and numerical results are presented in Section III and IV, respectively. Finally, Section V concludes the paper.

II. SYSTEM DESCRIPTIONS

A schematic diagram of a 2-D WH/TS OCDMA system using heterodyne detection receiver is shown in Fig. 2. A star $K \times K$ star coupler, i.e. K users in the system, is used to distribute the optical signal from one transmitter to all receivers.

At the transmitter, multi-wavelength signal from broadband source is modulated by binary data to generate on-off keying (OOK) signal. The OOK signal is then 2-D WH/TS encoded at a WH/TS encoder using a code generated by the code generator. In the encoding operation, bit "0" is unchanged while wavelengths of bit "1" signal are time-delayed and tuned in wavelength at the WH/TS encoder, which are determined by the time spreading and hopping patterns of the code, respectively. Wavelengths are then combined and the encoded signal is transmitted into optical channel together with signals from other users.

At the receiver, the received signal (including MAI) is first mixed coherently with a local oscillator (LO). The LO is also a broadband source whose characteristics (spectra, wavelengths, and separation between them) are the same as the one at the transmitter. When the received signal is passed through the WH/TS decoder, wavelengths from the desired user will be matched and the desired signal will be reconstructed by canceling the relative time delays. Wavelengths from interfering users that are either unmatched or differently delayed will be removed. On the other hand, those pulses, whose wavelengths are matched and delays are coincided, will be collected and become MAI. The decoded signal is converted into an electrical signal by a photodetector (PD). It is at the PD, OBI will occur due to the beating between chip pulses with nearly the same wavelengths. The photocurrent is passed through a bandpass filter (BPF) to filter out crosstalks, converted to the baseband by demodulator, and then followed by a low-pass filter (LPF). Finally, the binary data is recovered by a threshold detector. The demodulation can be carried out either synchronously or asynchronously, however, for the simplicity of calculation, we will only consider the synchronous case in this paper.

Several code sets have been proposed for a 2-D WH/TS OCDMA system. In this paper, we use prime code [9] for both time spreading and wavelength hopping. For the time spreading patterns, each code is a sequence of p_s blocks and each block has exactly p_s chips (i.e. the sequence length is $N = p_s^2$), where p_s is a prime number. In each of these blocks, there exists only one chip pulse (i.e. the chip value is "1"). The positions of chip pulses in blocks of a code are determined by one of p_s spreading patterns, which are constructed of prime sequences corresponding to the prime number p_s. A similar scheme is used for creating wavelength hopping patterns using a prime number p_h, which is also the number of available wavelengths. Each chip pulse is assigned to one of p_h wavelengths. The selection of wavelengths for a code is determined by one of $p_h - 1$ hopping patterns because the hopping pattern that produces the same wavelength for all chip pulses is not used. As a result, for a given set of prime numbers p_s, p_h, we can have a 2-D WH/TS code set whose cardinality of $p_s \times (p_h - 1)$, autocorrelation peak of p_s, and maximum cross-correlation of one [9].

III. SYSTEM PERFORMANCE ANALYSIS

In this section, we theoretically analyze the performance of the 2-D WH/TS OCDMA system using heterodyne detection receiver and derive its bit error rate (BER). The impact of GVD will be taken into consideration along with other noise and interferences, including MAI, OBI, and receiver's noise.

A. Pulse Propagation Model

An optical pulse can be approximated as Gaussian shape, and its propagation model in a dispersive medium can be expressed as [3]. This conventional model is good for analyzing pulse broadening and peak power reduction effects in single-wavelength or wavelength-independent systems (such as WDMA system). In 2-D WH/TS OCDMA system, however, besides these effects, it is necessary to reflect the relative temporal shifting between two pulses (i.e. time skewing effect).

In order to describe time skewing effect, a new parameter reflecting the relative temporal shifting between two pulses needs to be calculated and added to the conventional model. We first select an arbitrary wavelength to be the reference one, e.g. λ_r. Without loss of generality, we assume the position of the reference wavelength in the time spreading sequence to be stationary during propagation. The relative temporal shifting between a wavelength λ_i and the reference one can be expressed as $(\beta_{1i} - \beta_{1r})L = \Delta\beta_{1i}L$, in which L is the transmission length, $\beta_{1r} = 1/v_{gr}$ and $\beta_{1i} = 1/v_{gi}$ with v_{gr} and v_{gi} are group velocities of the reference and wavelength λ_i, respectively.

Our proposed modified model with the new parameter for the optical pulse at wavelength λ_i, denoted as $s_i(t)$, then can be expressed as

$$s_i(t)= \sqrt{P_s}|A_i(t)| \exp[j(\omega_i t + \phi_i)], \qquad (1)$$

where P_s is received peak power. ω_i and ϕ_i are optical frequency and phase of the optical pulse corresponding to the wavelength λ_i. $|A_i(t)|$ is the normalized amplitude of optical pulse and written by

$$A_i(t)= \frac{T_0}{(T_0^2 - j\beta_{2i}L)^{1/2}} \exp(-\frac{(t-\Delta\beta_{1i}L)^2}{2(T_0^2 - j\beta_{2i}L)}). \qquad (2)$$

Here, L is transmission length. T_0 is the half-width of pulse (at 1/e-intensity point) and β_2 is GVD parameter.

B. Heterodyne Detection Receiver

As discussed in Sect. II, after passing through the WH/TS decoder, optical pulses that contribute to autocorrelation peak consists of desired and MAI pulses. There are p_s desired pulses, one pulse appears at each wavelength, i.e. total p_s wavelength are visible. Again, without loss of generality, the desired user's wavelengths can be denoted as $0 \le i \le p_s - 1$. Let k be the total number of MAI pulses at p_s wavelengths, where the number of MAI pulses at wavelength λ_i is denoted as k_i. k_i is the random variable ($0 \le k_i \le k$) and $k = \sum_{i=0}^{p_s-1} k_i$.

In order to express desired and MAI pulses, we used our proposed pulse propagation model (Eq. (1)). We denote ω_{di}, ϕ_{di} as optical frequency and phase of the optical carrier corresponding to the wavelength λ_i of the desired user; as well, denote ω_{cij}, ϕ_{cij} as optical frequency and phase of the optical carrier corresponding to the wavelength λ_i of an j-th interfering user (out of k_i), respectively, where j = (1,..., k_i). The total decoded signal then can be expressed as

$$\begin{aligned} E_s(t) &= \sum_{i=0}^{p_s-1} \sqrt{P_s}|A_i(t)| \exp[j(\omega_{di} t + \phi_{di})] \\ &\quad + \sum_{i=0}^{p_s-1}\sum_{j=1}^{k_i} \sqrt{P_s}|A_i(t)| \exp[j(\omega_{cij} t + \phi_{cij})]. \qquad (3) \end{aligned}$$

To simplify the calculation, we assume that transmitted power levels of any wavelengths are the same for all users. Also, the distances from all transmitters to the receiver are the same.

The LO at a specific receiver has p_s wavelengths corresponding to p_s wavelengths of its desired user's. We denote frequencies and phases of wavelengths of the LO as ω_{LOi}, ϕ_{LOi} with $i = (0, 1, ..., p_s - 1)$. For the sake of simplicity, we assume the powers are the same level at all wavelengths of the LO. The photocurrent at the output of the photodetector after removing constant direct-current (DC) component and cross talk can be expressed as

$$\begin{aligned} i &= 2\Re \sum_{i=0}^{p_s-1} \sqrt{P_{LO}P_s}|A_i(t)| \cos(\omega_{IFd} t + \Delta\phi_{IFdi}) \\ &\quad + 2\Re \sum_{i=0}^{p_s-1}\sum_{j=1}^{k_i} \sqrt{P_{LO}P_s}|A_i(t)| \cos(\omega_{IFc} t + \Delta\phi_{IFcij}) \\ &\quad + 2\Re \sum_{i=0}^{p_s-1}\sum_{j=1}^{k_i} \sqrt{P_s P_s}|A_i(t)|^2 \cos(\Delta\omega_{dij} t + \Delta\phi_{dij}) \\ &\quad + 2\Re \sum_{i=0}^{p_s-1}\sum_{j=1}^{k_i}\sum_{m=j+1}^{k_i} \sqrt{P_s P_s}|A_i(t)|^2 \cos(\Delta\omega_{cijm} t + \Delta\phi_{cijm}) \\ &\quad + i_{rx}, \qquad (4) \end{aligned}$$

where $\Re$ denotes the photodiode responsivity; the intermediate frequencies and phases of data and j-th interfering user are $\omega_{IFd} = \omega_{di} - \omega_{LOi}$ and $\omega_{IFc} = \omega_{cij} - \omega_{LOi}$ as well as $\Delta\phi_{IFdi} = \phi_{di} - \phi_{LOi}$ and $\Delta\phi_{IFcij} = \phi_{cij} - \phi_{LOi}$ for $i = (0, 1, ..., p_s - 1)$; and the frequencies and phases of primary and secondary OBIs are expressed as $\Delta\omega_{dij} = \omega_{cij} - \omega_{di}$, $\Delta\omega_{cijm} = \omega_{cij} - \omega_{cim}$ and $\Delta\phi_{dij} = \phi_{cij} - \phi_{di}$ and $\Delta\phi_{cijm} = \phi_{cij} - \phi_{cim}$ for any $m \neq j$ and $m, j \in (0, 1, ..., p_s - 1)$.

The first term in the Eq. (4) represents desired photocurrent and the second one represents the photocurrent caused by MAI. The third term is primary OBI representing the beating between desired pulses and MAI pulses. The fourth term is secondary OBI representing the beating among the MAI pulses. Finally, the last term i_{rx} represents receiver's noise.

C. Signal to Noise Ratio

Firstly, we consider the desired current, which is given by

$$i_d(t) = 2\Re\sum_{i=0}^{p_s-1} \sqrt{P_{LO}P_s}|A_i(t)| = 2\Re\sqrt{P_{LO}P_s}A_d(t), \qquad (5)$$

where $A_d(t) = \sum_{i=0}^{p_s-1} |A_i(t)|$ is autocorrelation signal. The autocorrelation peak is corresponding to $t = 0$ which is also the time of thresholding. Without the impact of GVD, the autocorrelation peak (without MAI) equals to the code weight, p_s. Under the impact of GVD, time skewing and peak power reduction will make the autocorrelation peak decrease. At the thresholding time, the value of desired current will be $I_d = 2\Re\sqrt{P_{LO}P_s}A_d$, where $A_d = A_d(0)$ is the peak of autocorrelation.

Besides desired current, MAI current also contributes to autocorrelation peak. As $\Delta\phi_{IFcij}$ is assumed to be zero, MAI current hence can be calculated as

$$i_{MAI}(t) = 2\Re\sqrt{P_{LO}P_s} \sum_{i=0}^{p_s-1} k_i|A_i(t)|. \qquad (6)$$

The MAI current at thresholding time is written by

$$I_{MAI} = 2\Re\sqrt{P_{LO}P_s} \sum_{i=0}^{p_s-1} k_i|A_i(0)|. \qquad (7)$$

The value of $|A_i(0)|$ depends on MAI pulse's wavelength as shown in Eq. (2). Because the difference among β_{2i} is small, $|A_i(0)|$ has maximum value when $\Delta\beta_{1i} = 0$, which means that MAI pulse has the same wavelength with reference one. In this analysis, we will consider the worst case, all k MAI pulses are assumed to drop into reference wavelength. The value of $|A_i(0)|$ is now replaced by A_c, where A_c is received from Eq. (2) with $\Delta\beta_{1i} = 0$, $t = 0$, and β_{2i} equals to β_{2r} of reference wavelength. The MAI current is now expressed as

$$I_{MAI} = 2\Re\sqrt{P_{LO}P_s}kA_c. \tag{8}$$

The total of desired and MAI currents $I_b(b \in (0,1))$ can be expressed as

$$I_b = bI_d + I_{MAI}. \tag{9}$$

Next, to calculate OBI power, distribution of k interfering pulses over p_s wavelengths should be considered. Denote $\kappa = (k_0, k_1, ..., k_{p_s-1})$ as the p_s dimensional vector that represents the distribution of k interfering pulses over p_s wavelengths. It is seen that κ is a random variable that can be modeled as a multinominal distribution with an equal probability $P_i = 1/p_s$ [8]. By averaging the secondary OBI component, the OBI power for two cases $b = 0$ and $b = 1$, which includes primary and secondary OBI, can be derived from [6] as

$$i^2_{OBIb} = 2B_e\tau_c\Re^2P_s^2{A_c}^4(bk + \frac{1}{p_s}\binom{k}{2}), \tag{10}$$

where B_e is photodetector electrical bandwidth and τ_c is coherent time of the broadband source which can be approximated as $\tau_c = 1/B_0$ where B_0 is the optical bandwidth.

Finally, we calculate the receiver noise power, which includes shot noise $i_s^2 \approx 2p_seB_e\Re P_{LO}$(note that the shot noise from the p_s LOs is dominant as $P_{\mathrm{LO}} \gg P_s$) and thermal noise $i_{th}^2 = 8\pi k_BT_nB_e^2C$ [7]. Where e is the electron charge, k_B is Boltzman's constant, T_n is the receiver noise temperature, and C is the receiver capacitor.

Total noise variance, i^2_{nb} $(b \in (0,1))$, is expressed as follows

$$i^2_{nb} = i^2_{OBIb} + i^2_s + i^2_{th}. \tag{11}$$

Each bit is detected by comparing the autocorrelation peak with a threshold current I_D. The signal to noise ratio (SNR$_b$) for two cases ($b = 0$ and $b = 1$) at the thresholding time is calculated as

$$SNR_b = \frac{(I_b - I_D)^2}{i^2_{nb}}. \tag{12}$$

D. Bit Error Rate (BER)

We assume that there are $K-1$ interfering users, i.e. K simultaneous users, in which i users (out of the possible $K-1$) are sending "1". For any user, the probability of transmitting "0" or "1" is assumed to be equally likely. Therefore, i can be modeled as binominal variable with probability 1/2. Among i interfering users sending bit "1", we assume that there are k pulses matched with desired user's code. Denote $\langle\mu_\lambda\rangle$ as the average number of wavelengths common to a pair of two codes, the probability that one pulse is matched with desired user's code is $\langle\mu_\lambda\rangle/p_s^2$. k thus can be also modeled as binominal variable with probability $\langle\mu_\lambda\rangle/p_s^2$.

In order to minimize the BER, we consider the case that I_D is optimum [10]. Moreover, the demodulated photocurrent as well as noises can be modeled as Gaussian random variables, the total probability of error hence can be calculated as [6]

$$P_e = \sum_{i=1}^{K-1}\binom{K-1}{i}2^{-(K-1)}\sum_{k=1}^{i}\binom{i}{k}(\frac{\mu_\lambda}{p_s^2})^k(1-\frac{\mu_\lambda}{p_s^2})^{i-k}\times \times Q(\frac{I_1 - I_0}{i_{n1} + i_{n0}}), \tag{13}$$

where

$$Q(x) = \frac{1}{2\pi}\int_x^\infty \exp(-y^2/2)dy. \tag{14}$$

Here, I_1 and I_0 are derived from Eq. (9) correspondence with $b = 1$ and $b = 0$. The average number of wavelengths common to a pair of two codes μ_λ, in case of prime sequence with $p_s < p_h$, can be estimated as [2]

$$\mu_\lambda = \frac{1}{\binom{p_h}{p_s}}\{\binom{p_h-1}{p_s-1}\frac{(p_s-1)(p_s-2)+(p_h-2)}{p_h-2} + \binom{p_{h-1}}{p_s}\frac{p_s(p_s-1)}{p_h-2}\}. \tag{15}$$

Note that in the case of $p_s = p_h$, the average number of wavelengths common to a pair of two codes, μ_λ, equals to p_s.

IV. NUMERICAL RESULTS

For the numerical result, we use WH/TS sequences that have $p_s = 7$ and $p_h = 11$, i.e. the maximum number of users is 70. With the user's bit rate is 1 Gbit/s, the full-width at half maximum of the chip pulse [3] can be chosen as 10 ps. The 11 wavelengths are at the window 1550 nm and range from 1445 nm to 1555 nm (i.e. the wavelength interval is 1 nm).

The transmission mediums used in the analysis are the standard ITU-T normal SMF and DSF with the attenuation is approximately 0.2 dB/km. The dispersion parameters are also based on ITU-T recommendation. In order to have fair comparison with other systems, the numerical results are considered under a constraint on fixed power per bit. Under this constraint, the transmitted power per chip P_0 can be derived from transmitted power per bit P_b as $P_0 = P_b/p_s$.

A. Analytical Results for the Case of SMF

We first investigate the maximum transmission length when the system is affected by GVD and the SMF is used. Figure 3 shows the system's BER vs. the transmission length when the transmitted power per bit P_b = -5 dBm and the number of users K = 32 × 1 Gbit/s users. In order to analyze different GVD effects on the system performance, three cases of BER: without GVD, with pulse broadening and power reduction effects (these two effects occur concurrently), and with full impact of GVD (including time skewing), are shown.

It is seen that when only pulse broadening and peak power reduction effects are considered, the maximum transmission length of the analyzed system is reduced from 147 to 63 km,

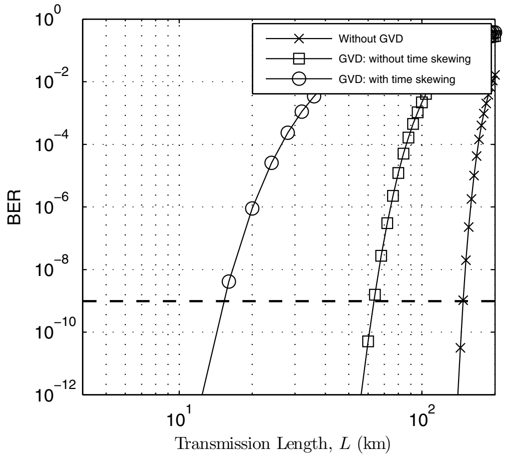

Fig. 3. BER versus transmission length L when $K = 32 \times 1$ Gbit/s users and P_b = -5 dBm. Transmission medium is SMF.

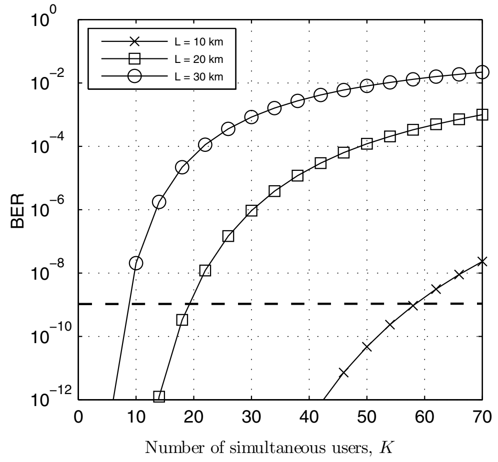

Fig. 4. BER versus number of simultaneous users when P_b = -5 dBm. The user bit rate is 1 Gbit/s and transmission medium is SMF.

which is still considered good enough for systems like access networks. However, when time skewing effect is included, it is extremely shortened, i.e. 15.5 km. This reveals that the time skewing is dominant effect in the 2-D WH/TS OCDMA systems.

Next, in Fig. 4, we show the reduction of the number of supportable users when the transmission length increases. We keep the transmitted power per bit P_b = -5 dBm and increase L from 10 to 20 and 30 km. The number of supportable users will decrease from 58 to 19 and 9 users respectively.

Figure 5 shows the system's BER versus transmitted power per bit when $K = 32 \times 1$ Gbit/s users and L = 15.5 km. Although the impact of pulse broadening and power reduction are not as much as that of time skewing, its power penalty is considerable, i.e. 11 dB in the total of 27 dB is shown. This is due to high dispersion coefficient of SMF and relative small pulse width (i.e. 10 ps).

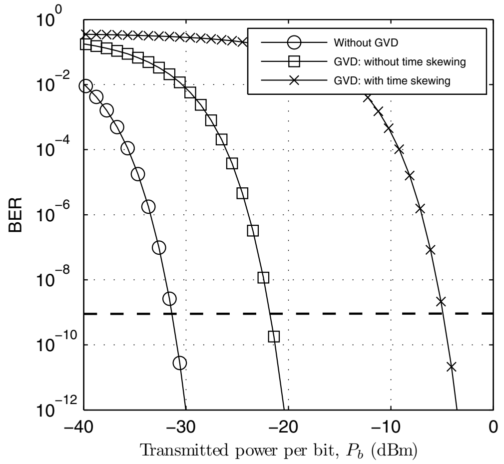

Fig. 5. BER versus number transmitted power per bit when $K = 32 \times 1$ Gbit/s users and L = 10 km . Transmission medium is SMF.

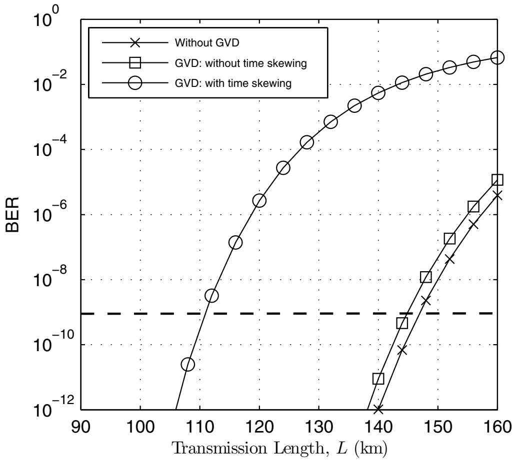

Fig. 6. BER versus transmission length (L) when P_b = -5 dBm and $K = 32 \times 1$ Gbit/s users. Transmission medium is DSF.

B. Analytical Results for the Case of DSF

In this section, we investigate BER of the system using DSF and compare with the case of using SMF.

As depicted in Fig. 6, the impact of pulse broadening and power reduction is significantly relieved when DSF is used. In comparison with the case of without GVD, the transmission length is only 2 kilometers shorter (i.e. 145 km compared with 147 km). In addition, the impact of time skewing is also reduced, which make the total impact of all GVD effects remarkably decrease. With the same transmitted power per bit (P_b = -5 dBm), the system using DSF can support 32 users with the maximum transmission length of 111 km. It is 7 times greater than that of using SMF.

Figure 7 illustrates the system's BER against the number of simultaneous users when P_b = -5 dBm and the user bit rate is 1 Gbit/s. In comparison with the system using SMF (Fig. 4), the system using DSF can support more number of users

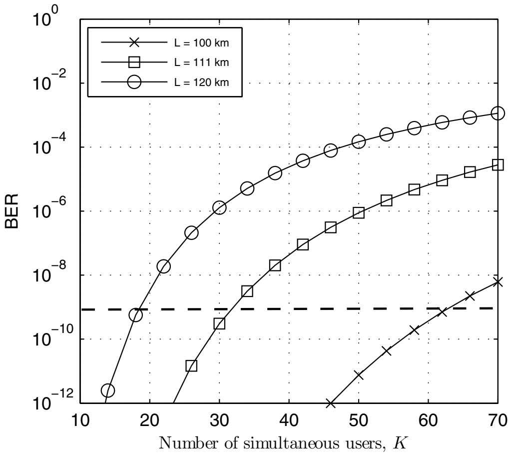

Fig. 7. BER versus number of simultaneous users (K) when P_b = -5 dBm. The user bit rate is 1 Gbit/s and transmission medium is DSF.

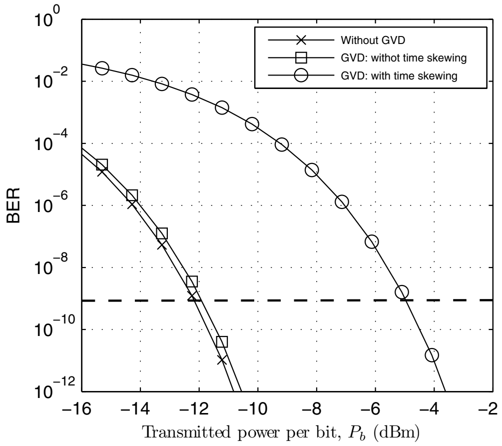

Fig. 8. BER versus number transmitted power per bit P_b when $K = 32 \times 1$ Gbit/s users and L = 100 km . Transmission medium is DSF.

and longer transmission length. For example, the system using DSF can support 32 users at L = 111 km compared with 19 users at L = 20 km of the system using SMF.

Finally, we investigate system's BER against transmitted power per bit when L = 111 km and K = 32 users. In order to keep BER $\leq 10^{-9}$ it is required to increase transmitted power to compensate power reduction because of GVD effects. As shown in Fig. 8 the power penalty of pulse broadening and power reduction is negligible. However, the impact of time skewing is still relatively strong. A power penalty of up to 7 dB is seen in the 2-D WH/TS OCDMA system with 111-km optical fiber length. More detail about the power penalty versus transmission length under the impact of GVD for the case of DSF is illustrated in Fig. 9.

V. CONCLUSIONS

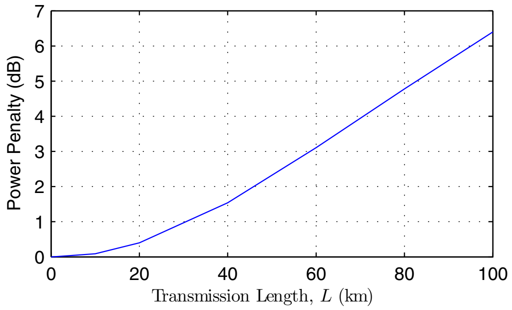

Fig. 9. Power penalty versus versus transmission length (L) when $K = 32\times$ 1 Gbit/s users. Transmission medium is DSF.

We have presented a comprehensive study of the impact of GVD on the performance of the 2-D WH/TS OCDMA system. A realistic model of Gaussian pulse propagation is proposed and heterodyne detection receiver is used so that the receiver's sensitivity can be improved. First, the impact of GVD on Gaussian chips propagating in optical fiber was analyzed. Then the system performance was investigated taking into account various kinds of noise and interferences, including MAI, OBI, and receiver's noise. The results show that, under the impact of GVD, the number of supportable users is extremely decreased and the maximum transmission length is remarkably shortened in the case of normal single mode fiber is used. The main factor that limits the system performance is time skewing. How the impact of GVD is relieved by dispersion-shifted fiber was also shown in this paper.

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