DISPERSION EFFECT AND MULTIPLE ACCESS INTERFERENCE ON OCDMA SYSTEM

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ABSTRACT : Optical Code Division Multiple Access (OCDMA) is an optical processing system which allows multiple users to share the same bandwidth simultaneously without interfering with each other using unique optical codes. As the number of user increases, the dispersion and multiple access interference begin to rise, which led to high bit error rate and low quality of service of the system. This paper presents the effect of Dispersion and Multi Access Interference (MAI) of optical fiber on the Bit Error Rate (BER) performance of a Direct Sequence Optical Code Division Multiple Access (DS-OCDMA) network. By using Matlab simulations, Signal-to-Noise Ratio (SNR) versus Received Optical Power (ROP) of an OCDMA transmission system can be evaluated for different numbers of system users. Mat lab simulations can be performed in order to illustrate the reduction of the dispersion index gamma, or to visualize different scenarios, e.g., what amount of transmitted power is required in order to obtain a BER of 10^{-9} when the length of the optical fiber is increased.

*Keywords***: OCDMA, BER, MAI, OOC, ROP, SNR**

1. INTRODUCTION TO OPTICAL COMMUNICATION

Optical Code Division Multiple Access (OCDMA) technique has been paying more attention recently due to its much advantage. One of the main advantages of OCDMA technique is supporting many users to access the optical network simultaneously and asynchronously by allocating the unique code to each user. However, when the many users involved the OCDMA system, the system performance will be degraded due to the Multi Access Interference (MAI) Spectral Amplitude Coding(SAC) OCDMA scheme has the talent to reduce the MAI by using code with fixed cross correlation . Many new codes have been proposed for OCDMA systems in recent years to eliminate the MAI effect.

One goal when designing OCDMA systems is to achieve desirable properties of the transmitted and received signals especially to reduce the impact of the MAI. MAI is the interference resulting from other users transmitting at the same time, which is the main effect limiting the effective noise performance for the overall system [1]. Various schemes have been investigated in order to increase the number of OCDMA's active users while at the same time reducing effect of the MAI [2]. Several code families have been developed for OCDMA such as Zero Cross Correlation codes [3], M-sequence codes [4], Optical Orthogonal codes [5], Prime codes [6] etc. However, these codes suffer from certain limitations such as the code either too long (e.g. Optical Orthogonal Codes and Prime Code), construction are complicated or cross correlation are not zero. The key to an effective OCDMA system is the choice of efficient address codes with low or almost zero correlation properties for encoding the source.

2. ADVANTAGES OF OPTICAL FIBER COMMUNICATION

Communication using an optical carrier wave guided along a glass fiber has a number of extremely attractive features, several of which were apparent when the technique was originally conceived. Furthermore, the advances in the technology to date have surpassed even the most optimistic predictions, creating additional advantages. Hence it is useful to consider the merits and special features offered by optical fiber communications over more conventional electrical communications. In this context we commence with the originally foreseen advantages and then consider additional features which have become apparent as the technology has been developed.

(a) Enormous communication capacity: In general, the capacity of communication depends on the carrier frequency. The higher the carrier frequency, the larger the available transmission bandwidth and thus the greater information capacity of the communication systems. The optical carrier frequencies in the range of 1013 to 1016 Hz (generally in the near infrared around 1014 Hz or 105 GHz) can yield a far greater potential transmission bandwidth than metallic cable systems (i.e., coaxial cable bandwidth up to around 500 MHz) or even millimetre wave radio systems (i.e., system currently operating with modulation bandwidths of 700 MHz).

(b) Low transmission loss: The attenuation or transmission losses in optical fibers are very low, in contrast with that in the best metallic cable. Optical fibers have been fabricated with losses as low as 0.2 dB/km. With the advances of technology of fiber-optic manufacturing, optical fibers with lower attenuations will be made and they will facilitate the implementation of communication links with extremely long repeater spacing (long transmission distances without intermediate electronics), thus further reducing both communication system cost and complexity.

(c) Small size and weight: Optical fibers have very small diameters, which are often no greater than the diameter of a human hair. Even when such optical fibers are covered with protective coatings they are far smaller and much lighter than corresponding copper cables.

(d) Ruggedness and flexibility: Although protective coatings are essential, optical fibers may be manufactured with very high tensile strengths. Perhaps surprisingly for a glassy substance, the fibers may also be bent to quite small radii or twisted without damage

(e) System reliability and ease of maintenance: These features primarily stem from the low- loss property of optical fiber cables which reduces the requirement for intermediate repeaters or line amplifiers to boost the transmitted signal strength. Hence with fewer optical repeaters or amplifiers, system reliability is generally enhanced in comparison with conventional electrical conductor systems.

3. MOTIVATION AND OBJECTIVE

Fiber Optics technology has becomes the new leads for digital communication during this decade. From communication systems that's hybrid between optical domain and electrical domain, till a full communication system undergoes only optical domain humans tends to puts a lot of effort on researching,

testing and implementing. As is the demand for speed, data rate, throughput growth rapidly. As many researches are conducted throughout the world, optical fibre communication has become the renowned technology.

. Multiple access techniques are required to meet the demand for high-speed and large capacity communications in the optical networks, which allow multiple users to share the huge fibre bandwidth. There are two major multiple access approaches: each user is allocated a specific time slot in time-division multiple access (TDMA), or a specific frequency (wavelength) slot in wavelength division multiple access (WDMA). Both techniques have been extensively explored and utilized in optical communication systems. Alternatively, optical code-division multiple-access (OCDMA) is receiving increasing attention due to its potential for enhanced information security, simplified and decentralized network control, improved spectral efficiency, and increased flexibility in the granularity of bandwidth that can be provisioned. In Optical CDMA, different users whose signals may be overlapped both in time and frequency share a common communications medium; multiple-access is achieved by assigning unlike minimally interfering code sequences to different transmitters, which must subsequently be

detected in the presence of Multiple Access Interference (MAI) from other users. MAI may be seen as a kind of noise, which is minimized in this research work by using the m-sequence signature code. OCDMA is the method of sharing the bandwidth of optical fiber among multiple active users. It plays a main role in digital communication, backbone networks, high speed LAN, MAN. Thus the main advantage of using optical fiber communication is high speed, large capacity and large reliability. Optical CDMA is most suitable to be applied to high speed LAN to achieve contention free, zero delay access, where traffic tends to be bursty rather than continuous. Optical systems use different types of optical codes. Codes can be bipolar or unipolar. In case of practical OCDMA network applications, the capacity of asynchronous multiuser access is essential. Furthermore, recent developments in coherent OCDMA encoders/decoders allow for the efficient separation of large number of simultaneously users providing thus a feasible solution for low-cost applications in multi-user Local Area Networks (LAN) environments [18]. In addition, an aspect of dispersion, namely the limitation of the OCDMA system is also presented here. The main focus of the dissertation is to do research on what can be done in order to reduce the dispersion of the OCDMA network such as to obtain a given bit error rate (BER).

4. OPTICAL ORTHOGONAL CODES (OOC)

Optical orthogonal codes (OOC) are a family of (0, 1) sequences with desired autocorrelation and cross-correlation properties providing asynchronous multi-access communications with easy synchronization and good performance in OCDMA communication networks. An optical orthogonal code is a family of (0, 1) sequences with good auto- and cross-correlation properties. Thumbtack-shaped auto- correlation enables the effective detection of the desired signal and low-profiled cross-correlation makes it easy to reduce interference due to other users and channel noise. The use of optical orthogonal codes enables a large

number of asynchronous users to transmit information efficiently and reliably. The lack of a network synchronization requirement enhances the flexibility of the system.

An optical orthogonal code (n, w, λ_a, λ_c) is a family C of (0, 1) sequences of length *n* and weight *w* which satisfy the following two properties.

1) The Auto-Correlation Property:

$$\sum_{t=0}^{n-1} x_t x_{t+\tau} \leq \lambda_a$$

for any x ϵ C and any integer t, 0 < t < n　　　　　　　　　　　　　　　　　(1)

2) The Cross-Correlation Property:

$$\sum_{t=0}^{n-1} x_t y_{t+\tau} \leq \lambda_c$$

for any x?y ϵ C and any integer t　　　　　　　　　　　　　　　　　(2)

   The numbers λa , λc are called the auto and cross-correlation constraints. The (0, 1) sequences of an optical orthogonal code are called its code words. The number of code words is called the size of the optical orthogonal code. From a practical point of view, a code with a large size is required. A desirable property of a code is that it should be as large as possible i.e. contains as many code words as possible. This is to enable more users to access the channel
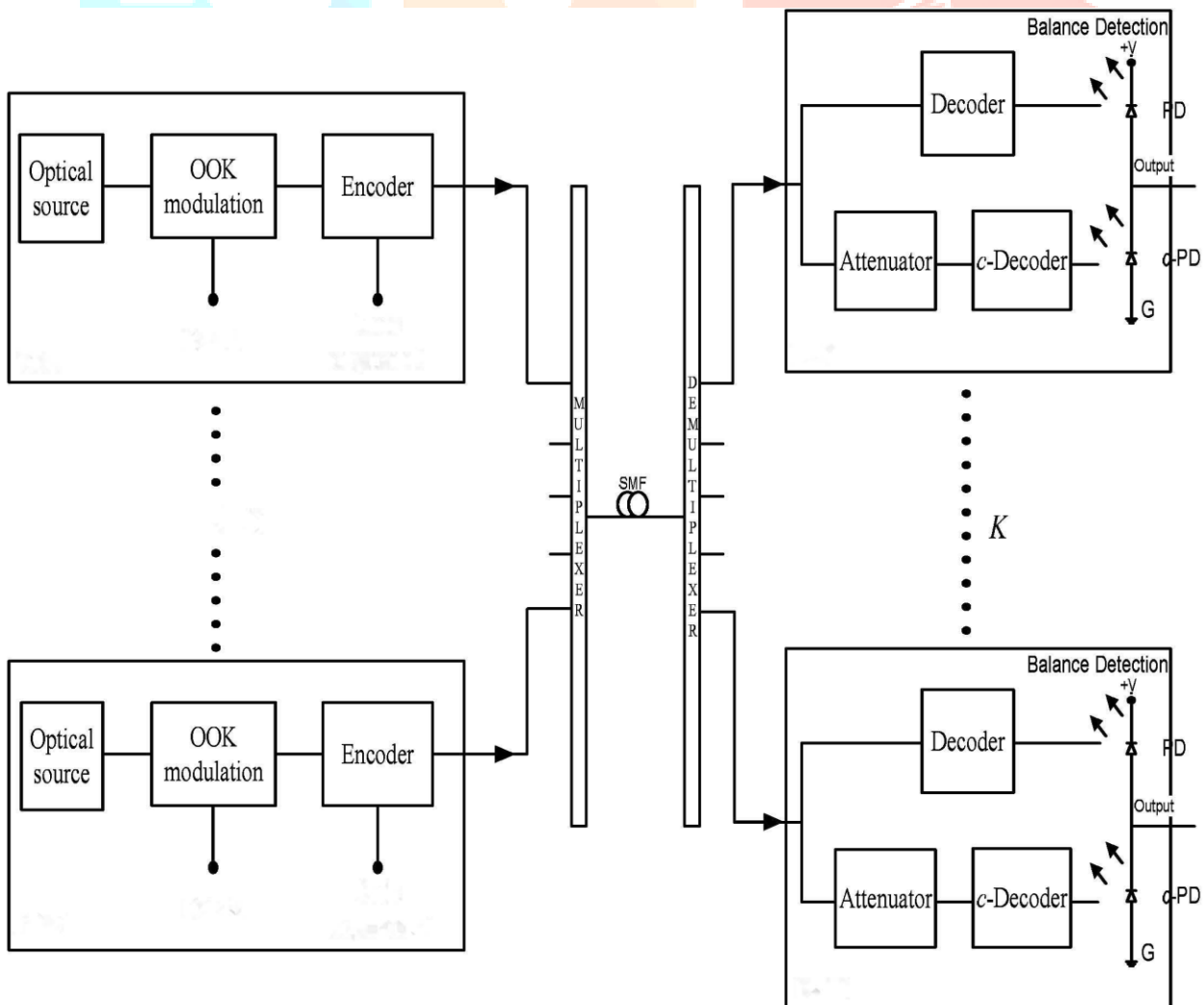
5. SYSTEM STRUCTURE

Fig 1.1 Typical OCDMA system architecture

The architecture of unipolar SAC-OCDMA system is illustrated in the Fig. 1.1. The OCDMA network considered includes several transmitters (T x) and receivers (Rx) placed in periphery of a star network configuration. Each transmitter is composed of a modulated source followed by an encoder. The broad-band incoherent source is assumed to be nonpo1arized, ideally flat over a bandwidth B_o.

The OCDMA encoders split the optical bandwidth into bins and assign codes to each user based on which set of bins is occupied. Encoded signals are distributed over the OCDMA network and assumed to arrive with equal power at the receiver.

The receiver side is composed of a 3-dBcoupler, an attenuator, a decoder, a complementary copy of the decoder called the c-decoder, and a balanced detector. The optical power is distributed to the decoder and the c-decoder by passing through the coupler attenuator. The transmission constant (α) of the attenuator is assumed to send adequate power ratio to the decoder and the c-decoder as required for any code family to assure that the interference signal has an equal power incident on each photo detector.

In the Optical code division multiple access (OCDMA) transmitter, to Sequence Inversion Keying (SIK) Modulated signal then drives a laser diode which gives the output S k (t) for kth user as follows –

$$S_k(t) = \sum_{l=0}^{N-1} P_t B_k \otimes A_k(t - lT_c) \tag{3}$$

Where P_t is the chip optical power for the k_{th} user at the transmitter output, l corresponds to the l_{th} chip, and is the operator that denotes SIK modulation such that either the sequence A(t) or its complement A(t) is transmitted for a 1 or 0 data bit, respectively. $S_k(t)$ is transmitted through the single-mode fiber, undergoing dispersion; it gives the output $S_k'(t)$ at the end of the optical fiber. For the k_{th} user, it is given as

$$S_{k'}(t) = \sum_{l=0}^{N-1} P_R B_k(t) S_{out}(t - lT_c) \otimes A_k(t - lT_c) \tag{4}$$

Where P_R the received optical power which is the difference between transmitted power and fiber loss, S out (t-lT_C) stands for the output pulse shape due to fiber chromatic dispersion, which is given by.

$$S_{out}(t - lT_c) = \sum_{l=0}^{N-1} \frac{1}{\sqrt{x\gamma}} e^{-i[(\frac{1}{\gamma})\cdot(\frac{t-lT_c}{T_c})^2 - \frac{\pi}{4}sgn(\gamma)]} \tag{5}$$

Here, γ indicates the index of chromatic dispersion of the optical fiber.

The Signal-to-Noise Ratio (SNR) at the Optical Correlator Receiver Output can be obtained as

$$SNR = \frac{U^2}{\sigma^2 + N_o}$$

$$N_o = N_{th} + N_{sh}$$

Where, N_o is the variance of noise, Nth is thermal noise of receiver, Nsh is shot noise of photo detector.

The Bit Error Rate (BER) at the Optical Correlator Receiver Output can be obtained as -

$$BER = \frac{1}{2} erfc \left[\frac{\sqrt{SNR}}{\sqrt{2}} \right] \tag{6}$$

6. SIMULATION TOOL

In this simulations work we use the MATLAB 9.3. The system is evaluated by means of $10*10^9$ chips/s. We tested the performance curve for bit error rate and signal to noise ratio considering wave length of 1550 nm, and single mode of optical fiber. Table 5.1 presents the parameters of the evaluated Optical CDMA system. It is also performed the eye diagram by means of 17 ps/km- nm dispersion coefficient. In the receiver, Electron charge ($1.6e^{-19}$c), Boltzmann constant ($1.38e^{23}$ /K Hz), Received optical power gain (-20), Dark current (10 nA), Thermal current($1\ pA^2Hz^{-1}$) are sed to simulate system performance.

7. RESULT AND DISCUSSION

Table 1.2 - Simulation Parameters in Optical CDMA Systems

| Symbol	Significance	Value
λ	Operating wavelength	1550 nm
b^c	Chip rate	10 Giga chip/s
Q	Electron charge	$1.6e^{-19}$ c
K^b	Boltzmann constant	$1.38e^{-23}$ W/K. Hz
T^r	Receiver temperature	300° k
R_L	Load resistance of receiver	50 O
R	Responsivity of each p-i-n photodiode	0.85 A/W
L	Length of fiber	245.05 Km
P_R	Received optical power gain	-20 dBm
N_{th}	Thermal current	$10^{-12}\ A^2\ Hz^{-1}$
N_{sh}	Shot noise	$3.128000000*10^{-50}$ A 2 Hz^{-1}
T	Time duration of each Data bit	350 ps
T_c	Time Duration of each sequence bit	50 ps
N	Code length	7
D	Chromatic Dispersion Coefficient	17 ps/nm-km [63]
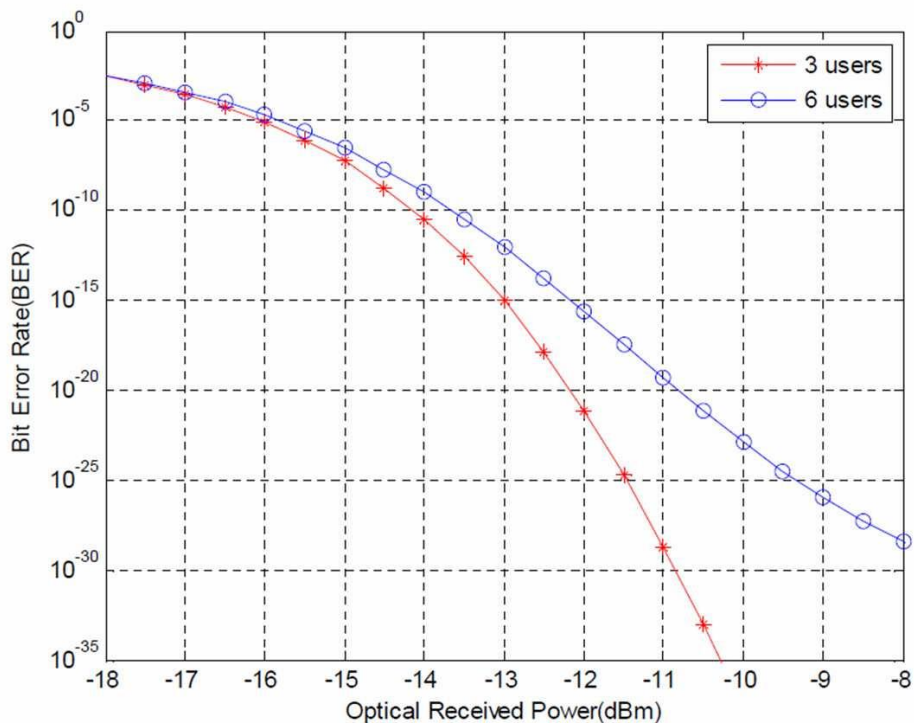
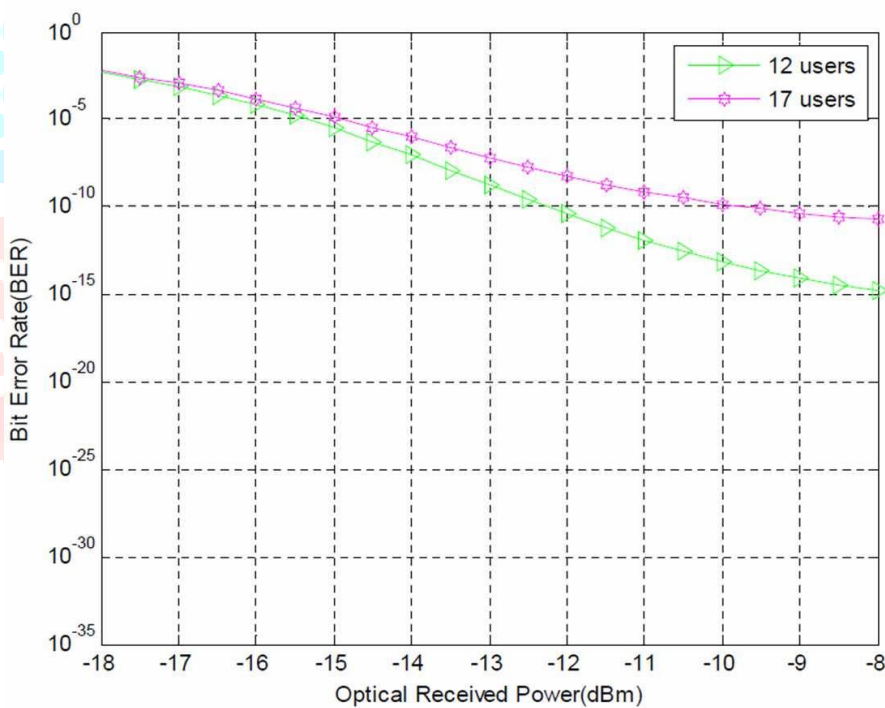Figure 1.3: BER Vs ROP for 3 and 6 users

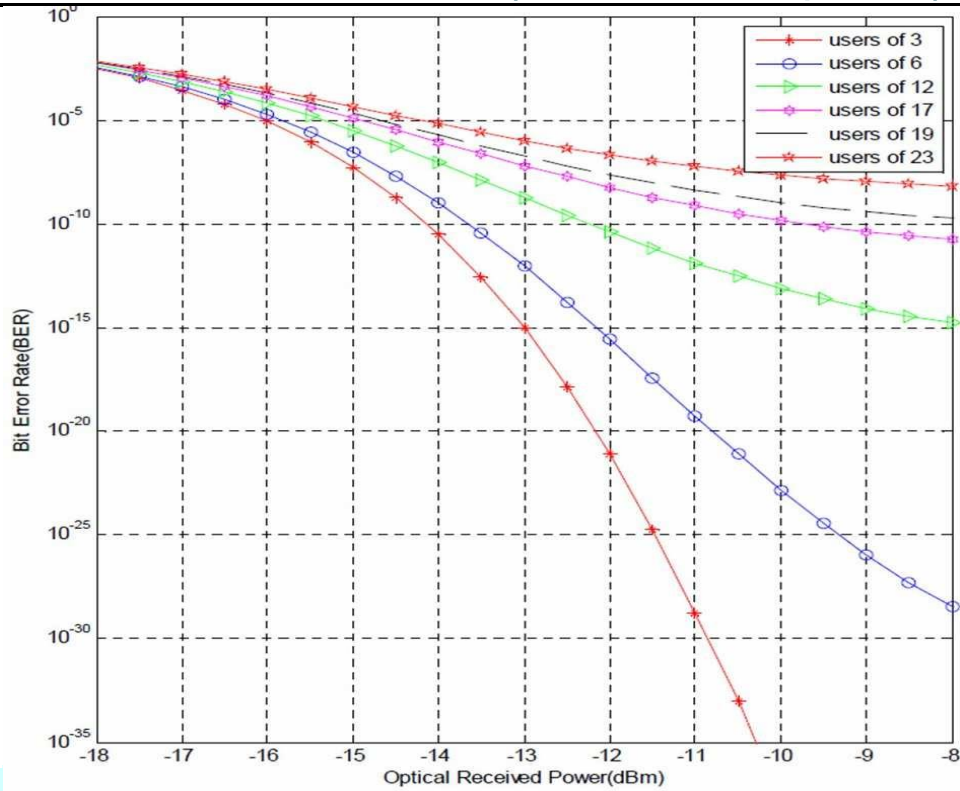
Figure 1.4: BER Vs ROP for 12/17 users
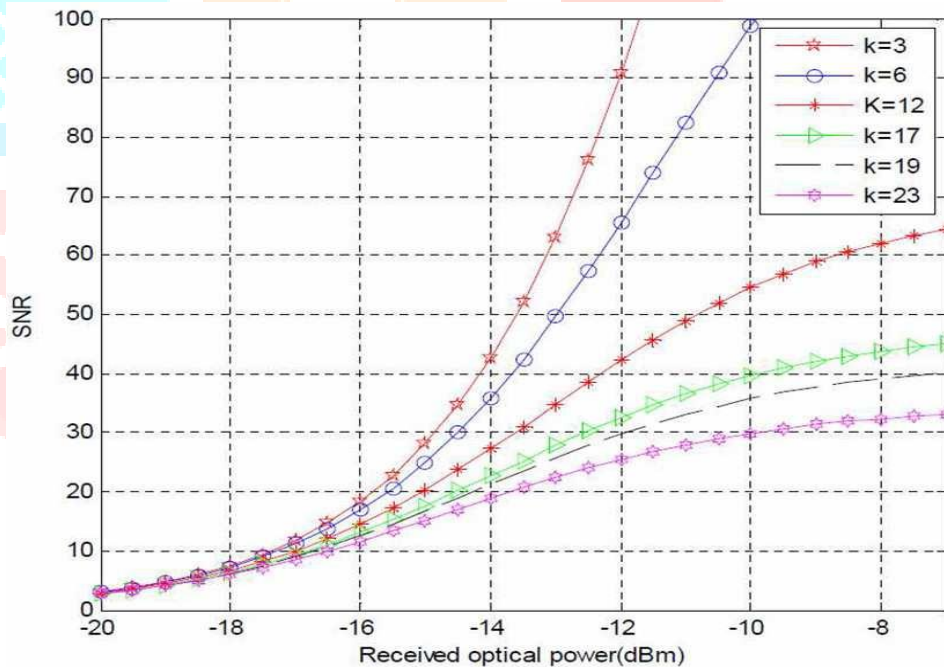
Figure 1.5: BER Vs ROP for different users

Figure 1.6: Performance comparisons -SNR vs. ROP

Figure 1.3, 1.4 & 1.5 below presents the system performance for BER versus received optical power (ROP) for 3 and 6 users, 12 and 17 users & illustrates the BER performance versus ROP for up to 23 users. We observe that BER decreases when the ORP and the number of users is increased. For instance, when we consider a 10 -5 BER, the ROP is - 14.8dBm for 19 users while for 23 users, this becomes - 14.2dBm.

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