Investigation of Effective Parameters for Improvement of OSNR and Increasing of the Channel Capacity in Optical Communication Systems

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Received: June 2017 Revised: September 2017 Accepted: October 2017

ABSTRACT:
Today, In Communication world, optical access networks play a fundamental role to secure and offer a wide band width to customers. Therefore, this use of communication ground of optic fiber, because of little diameter of optic cable rather than copper cable and undeniable capabilities of optic networks, is a new discussion of communication world of our country. In this regard, the way of optimum utilization of optic transition systems to residence location of customers with the minimum cost and the maximum capacity is the most important discussion of this matter that use of fiber to common house (FTTH) is an appropriate case for discussion, and with decrease of common access distance to fiber to the intended location, it makes facilities and advantages available for customers. The aim of this paper is explaining the parameters of an optic communication system to be able to determine and select the optimum communication system according to peripheral conditions, technical work range, and calculation of amounts of systemic parameters are determined in case with aim of access to desirable OSNR and increase of capacity of optic communication channels.

KEYWORDS: Optic access networks, Systemic specified parameters, OSNR, Channel capacity, fiber to common house.

1. INTRODUCTION

Optic fiber communications is growing rapidly since the first commercial installation of an optic fiber system in 1977. According to presented standards by the international union of telecommunication organizations, optic communication systems are categorized to three practical according to their applications:

Intra-organizational related to communication distances about 2 km Inter-organizational with short-range related to communication distances about 15 km.

Inter- organizational with long- range related to communication distances about 40 km in region of 1310nm wavelength and 60 km in region of 1550 wavelength[1].

The utilization of resources with 1310nm and 1350nm wavelength, and also considering standard optic fibers corresponding with international recommendations of telecommunications may be investigated in every categorizations.

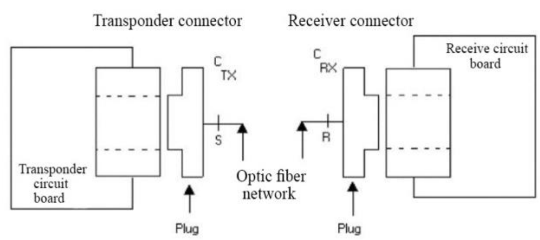


Fig. 1. The diagram of optic fiber communication system

2. FIBER TO THE PREMI (FTTP) SYSTEM

FTTP is a kind of optic connection in which optic fiber, directly enters a place where the user is there. This method sets against other methods of optic connection like Fiber To The Curb (FTTC), Fiber To The Nodes (FTTN), Hybrid Fiber Coaxial (HFC) in which the older methods are used such as copper wire and coaxial cable in order to transfer information in the access layer [3].

FTTP is categorized into two subsystems according to the place where fiber ends to there:

Fiber To The Home (FTTH): It is a kind of optic connection in which optic signal ends to residence/ occupation location of the user.

Fiber To The Building (FTTB): It is a kind of optic connection in which optic signal stops in a place near the residence/ occupation location of the user.

The primary works were done by FSAN group in 1990 decade in order to create an efficient structure for FTTH, then ITU considered some standards for two generations of PON.

2.1. Advantages of FTTH

One of the advantages of FTTH is that it has the possibility of faster connection in more distance than twisted pair cables, DSL lines, or coaxial cable.

The experts in FTTH council say fiber connections to house is the only technology with sufficient bandwidth for programmed run of subscribers apply with suitable price in coming decade. The most important advantage of FTTH is that it offers a high bandwidth and it is a trustworthy and efficient technology. In a network, the bandwidth is the ability of carrying the information, and the more information can be transferred with more bandwidth in a certain amount of time.

FTTH may offer a faster connection and the more capacity of transition from twisted pair. As on example, a couple of copper wire is just able to transfer six phone calls, while a couple of single fiber can transfer over 2.5 million phone calls simultaneously.

3. NEW TECHNOLOGIES IN THE FIELD OF DATA TRANSFER

To respond the increase of bandwidth without adding new fiber, there are three solutions: The first method is access to the systems with higher bit rate on the optic channels that is called time division multiplexing technique (Time Division Multiplexing (TDM)).

In TDM systems, after electronic multiplexing of channels, the act of converting the electrical signal to optic signal takes place by transponder for transfer by optic fiber, and at the end of the optic transfer line, the channels separate from each other electrically after detection of optic signal and converting it to electrical signal by de-multiplexing[6].

The second method is the installation of new fibers, and this solution may be the most economical option for networks which the cost of fiber installation is less for them.

The third method is called wavelength division multiplexing technique (Wavelength Division Multiplexing (WDM)). WDM method multiplex a number of signals carrying the light on an optic fiber by various wavelengths of laser light.

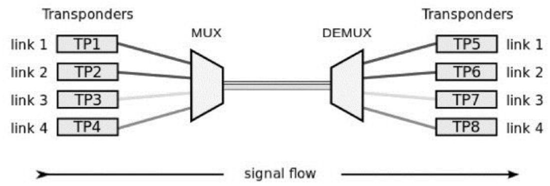


Fig. 2. WDM (Wavelength- division multiplexing)

In WDM System, there are two categorizations:

CWDM (Coarse wavelength division multiplexing) and DWDM (Dense wavelength division multiplexing). Both of them use several laser light wavelengths for signal transfer in a fiber.

The distance of CWDM is wider than DWDM. CWDM is able to transfer 16 wavelengths with channel distance of 20 nm in the spectrum range of 1270nm to 1610nm. But DWDM is able to transfer 40, 80 or 160 wavelengths with distances narrower than 0.8nm, 0.4 nm or 0.2nm from 1525nm wavelength to 1565nm of C Band or 1570nm to 1610nm of L Band. Certainly, DWDM enjoys a better performance to transfer more multiple wavelengths on a fiber[2].

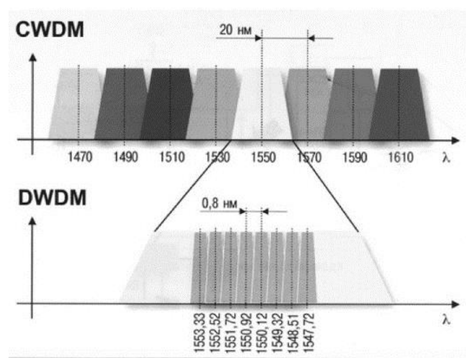


Fig. 3. DWDM and CWDM

DWDM amplified wavelength with less interference capability is used in long. The maximum board of CWDM is about 160km, but a DWDM amplified system, in case of periodic amplification of signal power in runtime, is able to transmit in a distance over these amounts.

In WDM systems with long distances, signal ration to optic nose decreases and optic pulse signal changes by the transfer because of the factors like: non-linear effects of fiber, reflection from connectors, color dispersion, dispersion and nose of ASE in optic amplifiers, therefore in optic systems, remaking the optic signal is essential (necessary).

The consecutive combination of transponders is used as digital repeaters too.

Forward Error Correction (FEC) transponder: Generally, these transponders are used to develop infrastructures of transfer systems of long distances under sea in systems with high bit rates > 10 Gbps and for terrestrial systems like leased lambda services[1]. These transponders reduce received errors in receiver's side. FEC technique is a method for correction of bits from one block which are erroneous. This means that one Bit 1 appears while bit 0 is sent and vice versa. The communication systems because of consecutive transmission of bits, there are some problems in losing one bit or receiving one additional bit which generally occurs.

The data block length must be fixed in FEC. All bits of one block are tested by a small block which is added at the end of the main block. Dealing with lower levels than SNR error level is possible by FEC, which leads that you can increase the distance between amplifiers or can increase signal bit rate. Today, FEC systems are used in lots of under-sea communication equipment[5].

3.1.Parameters of WDM network design

The parameters of WDM network design may be introduced as following:

The number of wavelengths

Bit rate of each wavelength

The distance between channels

The optic amplifier

The distance between optic amplifiers

The maximum length of transfer fiber without need to optic amplifier. The multiplication of the number of wavelengths in bit rate of each wavelength is determinative of capacity of WDM system. The capacity increases with the increase of optic bandwidth with higher efficiency that is the increase of bit rate of each channel to the distance between channels. The system bandwidth is limited by bandwidth of the optic amplifiers[7].

4. PARAMETERS OF OPTIC COMMUNICATION (CONNECTION) SYSTEMS

Regarding the figure 1, the sender optic parameters in S point, the receiver in R point, and the optic route has been considered between S and R points, which is of a great importance in designing an optic communication system. The parameters are determined in proportion to the purpose of access to desirable OSNR and a bit rate less than 10 in the manner of the maximum amount of dispersion and the attenuation of regarded optic route. These parameters may be expressed as following:

The range of working wavelength: It is necessary to consider communication system wavelength as wide as possible to provide the capability of flexibility in establishment of transverse compatible systems and enjoying of wavelength division mergers (WDM). The choice of range of working wavelength depends on several factors such as the kind of optic fiber, the features of optic resource, the level of attenuation and dispersion of optic route. The regions of system working wavelength specifies by the amounts of optic fiber cut wavelength or fiber cable. In T-G.652 and T-G. 653 fibers, these amounts are considered so that it allows single mode performance of cable in 1270nm and higher wavelength.

The kind of optic resource: Depending on the features of attenuation, dispersion and the hierarchy level in each intended application, the sender pieces include an optic resource. This optic resource, depending on application, may be considered as a light emission diode, length single mode laser, length multiple mode laser[4].

The spectral width of optic resource: In LEDs and MLM lasers, the width is determined with the maximum square root of width in standard working conditions. In measuring RMS widths, 20dB to 30dB lower than the maximum mode must be considered. In SLM lasers, the maximum spectral width is specified by the maximum total width of central wavelength. Which is 20dB lower than the maximum amplitude of central wavelength in standard working conditions. The average applicable power to optic fiber: The average applicable power in reference point of S is the average power of coupled. Pseudo random pulse fiber to optic fiber in sender side. This power is considered as allowed range in cost optimization, and it is a justification for needed extra power under the standard working circumstances for optic connectors drops, the measurement tolerance, and the exhaustion effects.

The route attenuation: The specifications of route attenuation are considered for the amounts of the worst manner, and they include boiling points drops, connectors, optic attenuators or other inactive optic pieces and other cable safety margin to cover underneath justifications:

A. Optimization in cable arrays/ B. The changes in performance of the optic fiber cable because of peripheral factors/ C. Drops of each connector/ D. optic attenuator or other inactive optic pieces between reference points of R and S. in recent years, fibers with linear improvement like PSCF are used which lead improving OSNR and the increase of capacity. Dispersion of optic fiber: In systems which have limitations from the perspective of dispersion, the maximum amounts of dispersion of route must be specified[9].

Dispersion compensation of optic fiber in WDM networks is necessary to improve the system performance and OSNR, so that dispersion compensator fibers are used to compensate dispersion.

The dispersion compensators in DM/DWDM systems compensate color dispersions and mode dispersion related to polarization.

Optic route reflections: The reflections are created by discontinuities of refractive index (coefficient) in optic route. The reflections cause decrease the system OSNR through their destructive effect on the laser performance or through increase of interference noise in receiver. The reflections may be controlled by determination of the following cases:

A. The minimum back drop of light from the cable in reference points of S and R.

B. The maximum separate reflections between reference points

The sensitivity of the receiver: The receiver sensitivity is the minimum average received power in R reference point which is calculated in exchange for 10-10 Bit error rate. This parameter includes power losses compensations caused by sender application under standard working circumstances, back drop of light in S point, receiver connector attenuations, and measurement tolerance. The receiver sensitivity does not include power losses caused by dispersion, time movement of pulses, or optic route reflections. These effect are considered in establishment of the maximum loss compensation of optic route separately.

The receiver saturation: the maximum average received power is expressed by receiver saturation and it is in R reference point in exchange for 10-10 bit error rate. This point is of a great importance that applying an optic attenuator is necessary in receiver input to prevent receiver saturation. The attenuation and non-linear effects from NIDSF fibers are used with huge effective level in WDM systems in order to improve dispersion effects which increases received power rate, OSNR, and information transfer rate with increase of effective level[10].

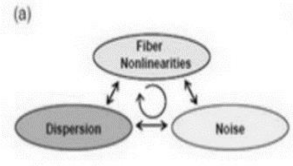
5. THE CAPACITY IN OPTIC TELECOMMUNICATIONS NETWORKS

The information carrying capacity in a communication channel is considered by Shannon first.

He calculated a channel capacity lacking memory with amplified white smartphone noise (AWSN) for signal noise ratio (SNR). Then, Gordon showed that amplified self- sustained effluxion (ASE) may be expressed by AWGN fields and it makes Shannon theory be usable for optic amplified systems. It should be expressed that three phenomena occur in these fibers simultaneously[8].

These phenomena are included: amplified self-sustained effluxion, color diffusion, and non-linear kerr fibers. (see the following figure (a)).

(a)



(b)

Number of spans	20
Span length	100 km
Dispersion $D\ (= -2\pi c\beta_2/\lambda_0^2)$	17 ps/(nm-km)
Loss coefficient α	0.2 dB/km
Nonlinear coefficient γ	1.27 (W-km)$^{-1}$
Symbol rate S	100 Gbaud
Channel spacing B	125 GHz
Mux and demux bandwidth	100 GHz
Optical frequency of central channel ν_c	193.55 THz
Spontaneous emission factor n_{sp}	1

Fig. 4. Effluxion effects and system parameters; a) Trip distributed phenomena created in optic fiber channel, b) Regarded parameters for system.

Here we have presented a method to assess an estimate in the ground of fiber channel capacity. This estimate is created using a modulation with the continuous spectrum, multilevel amplitude and phase modulation, false linear transfer with high speed, non-linear effluxion with initial deviation in sender and the similar detector. This analysis has proved all non-linear discussions related to momentary kerr fiber like signal interacts; non- linear noise[11].

5.1. Fiber emission(EFFLUXION)

The optical field conversion (E(z,t)) in the presence of chronic non-linear momentary kerr in fibers is defined as the following:

$$\frac{\partial E}{\partial z} + \frac{i}{2}\beta_2(z)\frac{\partial_2 E}{\partial t^2} = i\gamma(z)|E|^2 E + in(z,t)$$

Where $\beta_2(z)$, $\gamma(z)$, and fiber emission coefficient, and non-linear coefficient is as a function of emission distance in fiber. This section explains AWGN n(z,t) variable. This section is defined by the correlation of $< n(z,t)n*(z',t') \geq n_{sp}h\nu, \alpha\delta(z-z',t-t')$ where h is Planck invariable. δ is Dirac function. The emission curve slope is negative here because when the operation crosses from wavelength without emission, it has less effect on the emission. In turn, the emission curve slope may be engineered so that which reaches to zero. The loss compensation in fiber with distributed amplification has been used to maximize optic signal noise ratio (OSNR). The distributed OSNR is expressed by $P_s/2N_{ASE}B_{vof}$ to maximize optic signal noise ration which is delivered and N_{ASE} is the noise spectrum density on polarization. N_{ASE} is determined by $n_{sp}h\nu, \alpha L$ where L is transmission length here[4].

The correction of being non-linearity of ultra-channel is applied in sender (transponder). This operation will be done through reverse emission of channel in the absence of noise. This matter, deletes the channel memory regarding the pattern dependence of signal ultra-channel which is non-linear. To compensate the optical dispersion, we used dispersion map with single periodic mode which this map is optimized in the absence of compensation of being non-linearity of ultra-channel. The dispersion compensator elements, are considered as linear elements with little loss. The initial dispersion compensation is equal to 1050ps/nm. In this manner, the remaining dispersion in each pair is equal to 20ps/nm. (for each 100km) and the dispersion goes to zero in receiver[2].

5.2. Modulation and constellations

To reach the high capacity transmission, we need to create symbolic constellations with multiple levels and dense spectrum. The modulation which has been considered in this study, uses Nyquist signal which have box-shaped spectrum with the second (squared) root (originated from cosine shape).

In modulation, internal symbolic interference (ISI) does not occur. The cosine roll- off process has been used in order to decrease the huge memory in time period, that this time period is related to square spectrum modulation which uses since time function. The constellations in field uses a ring N structure (N-ASK). With the same range and random phases use PSK. The real number of needed phase manner in practical performance of this work follows the capacity results and used coding.

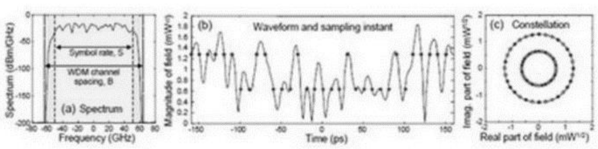


Fig. 5. An example of constellations and used field in this study

5.3. The capacity results

The Shannon capacity figure which obtained by $C = Blog_2(1 + SNR)$ equation, also has been used for comparison. In SNR Shannon equation energy ratio to bit (E/b) is noise ratio to bit (N/b). SNR related to Shannon is related to OSNR. $OSSNR = S/(2B_{ref})SNR$ is an equation in which S is signal symbol speed and B_{ref} is equal to 12.5 GHz. A it is shown in figure a, when SNR increases, a more number of ring is necessary to reach the Shannon capacity.

This matter has advantages in comparison to adding symbols on one or more rings. Figure a can be used to determine the capacity output from single ring (pure PSK) to multiple ring (N-ASK/PSK), in less powers of non-linear threshold[10].

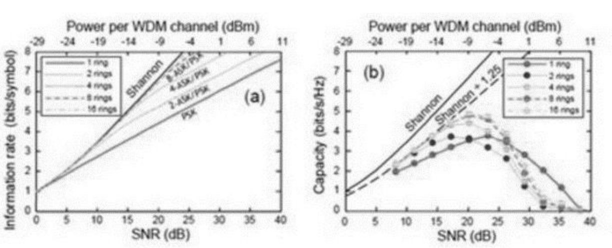


Fig. 6. a linear and non-linear system capacity (The capacity as a function of SNR in the absence of being non-linearity of b fiber) The capacity as a function of SNR for a 2000 km system

The capacity in figure b is expressed by bit on second on Hz. It is obtained by dividing the information speed. The information speed is expressed as bit on central channel symbol (B/S). the decrease in capacity is created by limitations in packaging the spectrum. The capacity reaches the maximum of 20dB SNR for a different number. For this special system, the capacity is limited by phase modulation (XPM). The calculation is done by 4 various noise and 4 groups of random phases have been used. These circumstances cause creating changes in the maximum capacity ($\pm 0.3 \mathrm{bits/s/Hz}$)[11].

6. THE SOLUTIONS FOR INCREASING THE CAPACITY IN OPTIC NETWORKS

To increase the capacity of network, the first solution, is enjoying more numbers of fibers to access the higher bandwidth which leads spending a lot of money and time. the second solution of speed increase, is using time division multiplexing (Time Division Multiplexing (TDM)) which provides more information transfer on the fiber with time division. But the possibility of sudden increase of speed is possible with this method. There is third solution for ISPs too, and that is WDM method. In this method, a special wavelength or a frequency is given to each one of input optic signals, and then all signals are sent on a fiber which leads increase of capacity.

What has made WDM such valuable and useful, are amplifiers which amplify optic signal without converting it to electrical signal. DBFA, EDFA amplifiers are included in these amplifiers which are used in wavelength band of 1530-1560 and 1528-1610nm respectively[6].

The next stage of capacity increase, is simultaneous use of two methods of WDM and TDM. In TDM method, the capacity increase is done with speed increase on a communication line.

While in WDM method, this process is done with various wavelengths and increase of communication lines. Therefore, with combination of these two methods, we can access to higher capacity on a fiber. In DWDM method, in the first decade of 1990, it was discussed that fiber can be used to transfer information in long/ far distances and vast networks. In DWDM method, the distance between channels which is used to send information, is 4nm, and each bandwidth channel provides 10Gb/s for the users. In CWDM method, the distance between channels is 20nm, and it is applied in C, S, E, O, L bands[8].

7. CONCLUSION

In this article (paper), the parameters are determined in case with access to desirable OSNR and bit error rate less than 10-10 in maximum dispersion and considered optic route attenuation. Using linear fibers such as PSCF and NZDSF with huge effective level in WDM systems has been recommended, which with increase of effective level, the received power rate of OSNR and information transfer rate will be increased too. Also, the next stage to increase the capacity, has been expressed the simultaneous use of two methods of WDM and TDM.

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