Simulative Analyzing of Covering Suburban Areas with 32 × 10 Gbps DWDM-PON FTTH Using Different Dispersion and Power

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Abstract —This paper contains an analyzing investigation of 32 channel - 10 Gbps DWDM-PON FTTH Simulate reaching a village in suburban area in environment that cannot put any sub node (amplifier or repeater) in the middle of the distance, therefore we design a system that deliver the CO signal directly from the OLT in the central of the city to the houses of the village all the way passive. to accomplish that we need a constant channel Spacing equal 100 GHz. with different dispersion (2,4,6,8,10 ps/nm.km) and power (-10, -5, -3,0,3,5,10) at the end of comparison of BER and Q factor for DWDM systems we reach a maximum distance 129 km with Q factor = 6.16 and BER = 3.44 e-10 in the presence of nonlinearities. This system can be severely limited by dispersion as we know smaller the dispersion the better the Q- factor but we will prove, not always the smaller the dispersion the better the Q-factor as we will see in some distance like 60,80 km the best performance is done with dispersion equal to 4, 6 and sometime 8 ns/nm.km not 2.

Index Terms—Dispersion, BER, Q-Factor, (DWDM- PON), FTTH, OPTISYSTEM

I. Introduction

In recent years we notice a rapidly increasing in technology because of the demand for high bandwidth from each end users ([1] and [2]). Passive Optical Networks is take into account as one of the method that are capable dealing with this request, due it can supply for each user a high bandwidth, also it is consider as a cost effective and demand minimum amount of maintenance because there is non-attendance of any kind of active equipment between the OLT and ONU such as repeater, switches etc ([3]-[6]). So deploying PONs for access network to become as a promising technique resolving to what we know "the last-mile bottleneck" ([7]-[9]).

A techniques called WDM-PON (Wavelength Division Multiplexing Passive Optical Network) is suggested to face the challenging growth in users high-bandwidth demand. So dozens of wavelengths in a single fiber can send simultaneously ([10] and [11]). now in Iraq for example it can reaches up to 192 wavelengths per single fiber and each wavelength can carry up to 100 Gbps this mean a single fiber can transmit up to 19.2 Tbps and this will make a jumps in the internet of Iraq.

We should put in our mined that the agreement of WDM-PON with presenting TDM-PON is a big necessity for NG-PON to be economical applicable [12]. But there is some disadvantage like the extra price in the designation of many wavelengths we must install an extra laser to produce these wavelengths in WDM-PON construction [13]. Fig. 1, shows a simple WDM-PON transmission components.

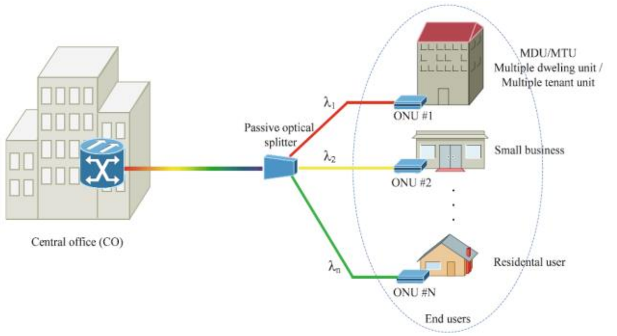

Fig. 1.WDM PON components [14].

The ITU (International Telecommunication Union) has standard in the channel spacing for WDM is a 100 GHz grid which has a frequency range from 186 to 196 THz (C band) equal to wavelength extend from 1530 to 1612 nm ([15] and [16]).

In spite of what we mention the huge rule WDM-PON can play, in the next several years' deployment it as FTTH is not yet expected ([17] and [18]).

But as we know before can supply a large amount of bandwidth so concentrate him at applications cost like transmit lines for Fiber-to-the-Cabinet (FTTC) and Multiple Dewing Units (MDU). In the FTTH application region, generality all the bandwidth consumable support includes distribution of video (digital with high definition); requesting a minimum bandwidth from 8 Mbps to 15 Mbps rely on the techniques used to pressure

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the video. Because this system has advantages of small price, simple maintain, open and soft evolvement for different kind of services [19]. in the near future must of our work will be dealing with digital multimedia services so, ultra-high definition television (UHDTV) service, 4K (4096×2160 pixels) and 8K (8192×4320 pixels), will arise as the need for some techniques that will expend maximum amount of data bandwidth in FTTH [20].

One of the basics we should know about the design of WDM PON is identical to the design of the PON. WDM-PON at most has ONUs or ONT at the end terminal mostly in the user house and an OLTs at center office [21].

As shown in Fig. 2, The major variation happened when numerous wavelengths work on one optical fiber or ONUs, they must work on different wavelengths. So numerous wavelengths on single fiber let us to either put additional bandwidth for every ONU or increase the number of ONUs for each distribution optical fiber system [22]. We should note that every ONU must divided the channel wavelength individually so let the signal connection happen to the OLT in case of downlinks and uplinks, this technique generates a point-to-point line of light in the midst of OLT and every ONU replacing the old techniques of point to multipoint line of light in the TDM-PON. so The MAC layer is simplified because point-to-point connections between OLT and ONUs are understanding in the wavelength domain [23]. In WDM-PON, each ONU can work at various rate that may reach the entire wavelength bit rate of the channel and without meeting the resource contest between the other ONUs also in WDM PON, every wavelength can run individually with a different velocity and protocol, and subsequently, the network has ability be upgraded each one Separately [24].

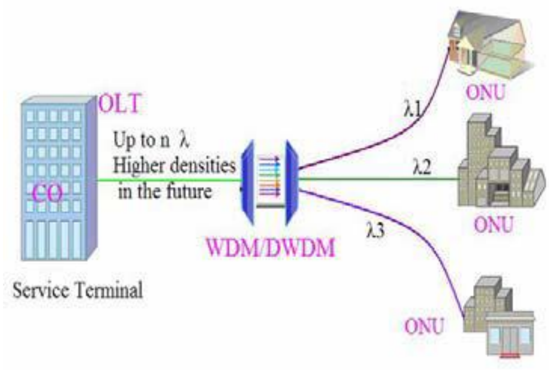

Fig. 2. Illustration of WDM-PON , [24].

Therefore, for that reason and many more other, WDM-PON is considered as the extreme favorable technology for network accessing because it has the ability to upgrade, increase capacity, and more security [25]. which can please the increasing need for higher data transmission speeds in current future ([26], [27], [28]). But the WDM is not enough specially when the optical transmission system request for rising in the number of channels wavelength per fiber and bigger data rate for encounter the data central applications so a dense-wavelength division multiplexed (DWDM) was propose [29].

DWDM is the most optimistic and eventual resolution utilizing a safety eye wavelength that are suitable employment for increasing capacity and bandwidth [30]. adopting dense wavelength division multiplexing (DWDM) transmission systems become an excellent solution for effective employment of fiber optical network in suburban areas without the requirement for set up extra optical fibers to the main backbone network. DWDM define as transmission system that can be more effective employment of optical fiber by multiplexing and in the same time sending a multiple of different wavelengths to a single optical signals [31].

The fully passive optical access long reach network represents a cost efficient settling for an optical access network. The durability of this optical techniques is its capability to replace the optical elements and electronics in the CO and make the network architecture as simple as possible for DWDM so it become Dense wavelength division multiplexing passive optical networks (DWDM-PON). By using an extended backhaul fiber this gave us the probably to supply data transmission in distance up to 129 km like in our case [32].

Thus, in extreme trade DWDM-PON systems, the channel spacing is less than 200 GHz, in our case we used 100 GHz (0.8 nm at 1552 nm). Using 50 GHz a frequency spacing in DWDM are actually now is under examination [33].

DWDM-PON are count as hopeful techniques after XG-PON large distribute. DWDM-PON can employ the main passive optical network component (OLT, ONU and ODN) as GPON and XG-PON using splitter based ODNs and colorless ONUs. This is a powerful feature for any new incoming techniques therefore it saves us a lot of expense when installing a new equipment and can applied, existence with ancient PON techniques. Fig. 3, shows the existence of DWDM-PON with existing PON techniques [34].

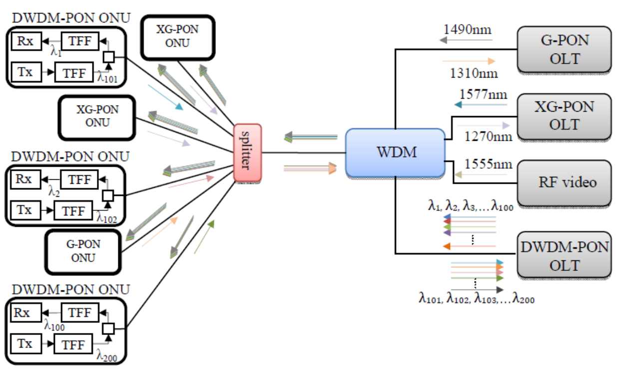

Fig. 3. The existence of DWDM-PON with existing PON techniques [34].

The achievement of having some high data rate communication systems in any optical fiber systems used for communication is limited by many elements like nonlinear effects, dispersion, and attenuation. But the big challenge of lost caused by dispersion ([35] and [36]). Dispersion define as the incoming transmitted signal components through fiber optic at various speed and detect in the receiver at various times

In another word A signal pulse starts from laser in the transmitter side pass through a fiber optic are defame at the receiver side as a result of this impact. So Dispersion is accumulative impact the longer the distance travel, the bigger the amount of dispersion. Standard single mode fiber (SSMF) carry a positive dispersion a mount a bout 16 ps/(nm ·km) at 1550 nm ([37] and [38]).

WDM-PON is a fascinating resolution to please the worldwide rising needs for transmission capability in spite of are badly restricted by dispersion [39].

II. Materials and Methods

As we see in the Fig. 4, the GPON has a maximum covering area is 60 km but farther then that we must put an active node to pre-amplifier the signal if we want to send it farther, so we design assuming to cover a village in environment like desert, sea or mountain that not allow to us to put any node.

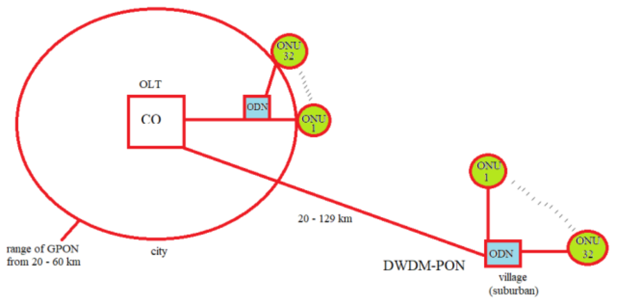

Fig. 4. The main map of our design

We chose DWDM - PON because it has a key advantage of possibility to improve the transition line by adding a more channel in the same single fiber so it can be grow in the near future and cover a large territory or another village. so we applied a variation in power and dispersion to discuss the performance of distance and how good and faraway the signal can reach. Fig. 4 shows a sketch of the area that we want to reach with our design.

For the reason mention above we must cover the suburban area (village) all the way passive from the OLT in the central of the city to the ONU in the houses of the village, working on this demand not easy to accomplished until we chose DWDM system because his ability to cover a long haul distance but it has some element that reduce the performance, one of the serious element is the type of fiber being utilized [40]. Another element is dispersion this is the main purpose of this article, manage the dispersion play a very important rule in any transmission systems specially in DWDM, Because of the differentiation types of fiber nonlinearities led to penalties affects the dispersion [41]. We try to prove that not always the smaller the dispersion the longer and better signal we get, so we try to an accomplish a good signal and appropriate distance to cover with an acceptable dispersion. Fig. 5, is the block diagram of our design using Optisystem program [42].

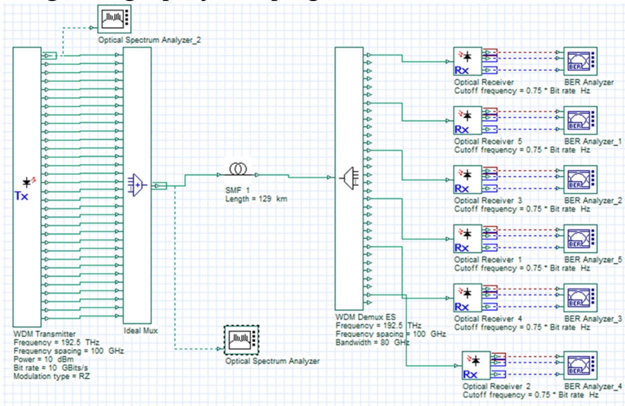

Fig. 5. The block diagram of DWDM-PON

A. *Multiplexing*

One of the main multiplexing technique has been exceedingly widespread around the earth is Time-division-multiplexing passive optical network (TDM-PON). In the TDM-PON, all the users participate the bandwidth of single wavelength. But with the rapid increasing in the need for bandwidth and the problem happened when we have a lot of end users finite by attenuation in the optical splitter for each wavelength (when we use optical system has 16 channel, the insertion loss of the power splitter will be very high it reach up to 14 dB) all that led to prevent any grow in the near future, it means the growth of the information community and the bandwidth for a single user sound finite, therefore decreases the expense of each user and this is a reversing what the future market requires [43].

So we go with multiplexing technique that make every user receives his own wavelength. Called wavelength Division Multiplexed Passive Optical Network (WDM-PON), utilizing WDM-PON techniques let us supply wavelengths in optical system up to 64 or even more -[44]. In the good side, utilizing a power splitter for downstream wavelength has a small insertion loss about 3 dB and this is allowing us to save power used to increase the distance or buy cheap not very sensitive receiver. we all know the DWDM-PON is derivative from WDM-PON the deferent is in the channel spacing the DWDM used less than 200 GHz and above 200 is WDM, in our design we used 100 [45].

B. *Simulation*

We used in our designs DWDM - PON system with different input transport power (-10, -5, -3, 0, 3, 5, 10) dB and different dispersion (2,4,6,8,10) ps/nm.km with RZ modulation format, then we apply it on different distance from 20 km up to 120 to represent the village location that we want to deliver our signal and analysis it is quality. So to accomplish that we need to discuss the component of our design [46].

1) *Transmitter section*

The DWDM system include transfer technology that authorize to generate a lot of wavelengths to proceed through a SMF. It may be run for many wavelength, so will be necessary to multiplexes them. The DWDM transmitter contain a PRBS generator, RZ data format, CW lasers and mach zehnder modulator (MZM) they all combine in WDM transmitter as shown in figure 6 then the output signal move to the ideal optical multiplexer [47]. All the transmitter section has the characteristic as shown in the Table I.

TABLE I: THE MAIN CHARACTERISTIC WDM TRANSMITTER

name	value	units
Number of output ports	32	
Frequency	192.5	THz
Frequency spacing	100	GHz
Power	-10 to 10	dB
Extinction ratio	10	dB
Linewidth	10	MHz
Initial phase	0	deg
Bit rate	10	Gbps
Modulation type	RZ	
Duty cycle	0.5	bit
Suppression ratio	30	dB

- PRBS pseudo random bit sequences generates data represent the bandwidth for each channel. A PRBS WDM Transmitter manage the data according to various operation demanded [48].
- Modulation format the most common modulation or data format has been used is RZ and NRZ so to serve deferent purposes a various other modulation formats have been suggesting. but we will focus on the main variation between NRZ and RZ and why we chose RZ for our design. NRZ for 1 bit substitution occupies the whole bit period at fixed power level. RZ is second mutual line code which occupies one and only a part of the bit period that rely on a duty cycle, standard duty cycle is 50 %. If NRZ and RZ line code bandwidths are contrast, then it is imaginable to decide that RZ line code take up around half bigger bandwidth than NRZ line code ([49] and [50]). RZ line code has also bigger tolerance to nonlinear impact like SPM, XPM and FWM and that is very important to us because we need to cover a long distance and the first enemy we faced is nonlinearity. further, the RZ line code is set to be less oversensitive to Inter-Symbol Interference (ISI) because to a minimal influence of NOE and so typically obtain better performance in the contrast to NRZ ([51] and [52]). Choosing of a suitable optical modulation format has large effect on the system execution, and this why we chose RZ. RZ is excellent as in the contrast to traditional NRZ systems for serving our purpose.
- Continuous wave Laser (CW) work as a modulation carrier signal wavelength of light that use to Generates light sources [53].
- The mach zehnder modulator MZM has three gates, the first gate for electrical modulation kind, the second one is the CW laser input and the third one perform the output of the optical signal. having a frequency spacing of 100 GHz. To spread between the signal an avoid the cross talk ([54] and [55]).

All the four part that was explain before are set in to one equipment we called it WDM transmitter as shown in Fig. 6.

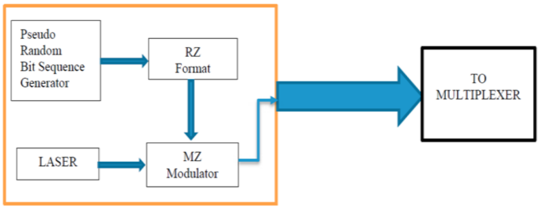

Fig. 6. A collective of modulated component inside WDM transmitter [56].

2) *Fiber section*

After the output signal that coming from multiplexer it transmitted through SMF without any amplifier or DCF then to demultiplexer. Primarily the length we used in our research (20,40,60,80,100,120) km standard single mode fiber optic. So SSMF represents the critical part that we depend to send our signal as far as passible [57]. The main characteristic of the SSMF in explain in Table II below.

TABLE II: THE MAIN CHARACTERISTIC OF SMF

name	value	units
Reference wavelength	1557	nm
Attenuation	0.2	dB/km
Dispersion	2-10	ps/nm/km
Dispersion slope	0.075	ps/nm^2/km
Differential group delay	0.2	ps/km
PMD coefficient	0.5	ps/sqrt(km)
Effective area	80	um^2
Max Length	20-120	km
nonlinear refractive index (n2)	2.6e-020	m^2/W

3) *Receiver section*

Here we receive the coming signal from MUX ES through the SMF to be detect in the 1x32 WDM demultiplexer where the signal is divided into 32 optical wavelengths and transmit to be received, and changed into a signal (in electrical form) After many operation is done like filtering using low pass Bessel filter (LPBF) which every channel is analyzed individually than, every channel is converted to electrical signal utilize PIN photodiode (whose reference frequency is in the range from 192.5–195.7) after that an optical filtering done using Bessel electrical filter to minimize the noise caused by electrical signal [58]. than using 3R regenerator to recreate the electrical signal so the signal can pass through data recovery to recreate the original electrical signal that help us to analysis the output signal by BER analysis by create a results and graphs such as Q-factor, eye diagrams and BER ([59] and [60]).

Therefore, Each ONT must Composed of receiver has a Bessel electrical filter, PIN photodiode and optical filtering. According to ITU-T recommendation the BER value for optical fiber receiver in any systems with every channel must has minimum bite error rate minimal than 10^{-10} so the signal can be detected clearly [61]. DWDM-PON simulation diagram composed of 32 channels according to the ITU-T G.694.1 to what was recommended [62]. The Table III, IV below show the main characteristic of WDM Demux ES and optical receiver respectively.

TABLE III. THE MAIN CHARACTERISTIC OF WDM DEMUX ES.

name	value	units
Number of output ports	32	
Frequency	192.5	THz
Frequency spacing	100	GHz
Bandwidth	80	GHz
Insertion loss	0	dB
Depth	100	dB
Filter type	Bessel	
Filter order	2	
Sample rate	128	GHz
Noise threshold	-100	dB
Noise dynamic	3	dB

TABLE IV: THE MAIN CHARACTERISTIC OF OPTICAL RECEIVER

name	value	units
Responsivity	1	A/W
Dark current	10	nA
Cutoff frequency	0.75 * Bit rate	Hz
Insertion loss	0	dB
Depth	100	dB
Order	4	
Center frequency	193.1	THz
Sample rate	5 * (Sample rate)	Hz
Thermal noise	1e-022	W/Hz

III. RESULTS AND DISCUSSION

In order to make the DWDM system work with a suitably minimum BER and reduce the bad performance retreating caused by dispersion a new design with improved techniqes is needed. Which must be sutabile for our situation, that we can not put any active part in the midell of the distance and we want to used SMF without DCF so to achieve that we design DWDM-PON as shown in Fig. 5 and analysis the out put for a defferent power and dispersion as shown in the figures below.the biginig result as shown in Fig. 7, which expalin the out put of the MUX after combining the 32 wavelength.

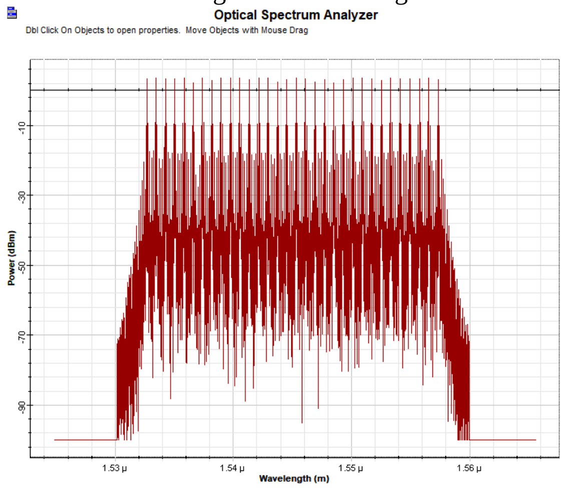

Fig. 7. Transmitted Spectrum of DWDM

Due to previously mentioned destructive influence on fiber optice transmition system performance,

The magore job of this design is to analysis the performance of these coverge distance that simulate the village location and find the maximum range with sutable dispersoin and power as we will see in our investigated of DWDM-PON simulation scheme.

As one can see in Fig. 5, we did not use any DCM and optical EDFA amplifier we depend only on the power of transmition that are variable from -10 to 10 dB over the SMF fiber of 20,40,60,80,100,120 km in length, the maximal transmission line length, with 10 Gbps transmission bite rate is 129 km with (Q factor = 6.16 and BER = 3.44 e-10) span with BER<10^{-10} is achieved.

We notice the system is severely affected by dispersion, from previous studies we see that smaller the dispersion the better the Q- factor but as we see not always the smaller the dispersion the better the Q-factor as we notice in the figure below in different distance like

As shown in figure above that 80,100,120 km has the best performance is done with dispersion equal to 4 not 2 ps/nm.km as it supposes in the C band that we used for the dispersion equal to 4,6,8,10 it reaches maximum performance in distance like 80,60 ,40,20 km respectively so we found in the distance from 20 up to 80 km the longer the distance the smaller the dispersion that is make the signal performance is perfect.

In another hand in distance like 20, 40, 60, 80 km the worst performance is done with dispersion equal to 2 ns/nm.km and this is very awkward. because to smallest amount of 2 compared to other, should gave as it was supposing the perfect Q-factor, this mean the C band with 2 dispersions are not suitable

Now in the power side we notice that not always the bigger the power the better the performance(Q-factor) will be, as we see in

- Distance 20 km in Fig. 8 the better Q-factor is done with power equal to 0 and dispersion 4 also with power equal to 5 and dispersion equal to 10
- Distance 40 km in Fig. 9 the better Q-factor is done with power equal to 3 and dispersion 2.
- Distance 60 km in Fig. 10 the better Q-factor is done with power equal to 5 and dispersion 6
- Distance 80,100,120 in Fig. 11, Fig. 12, Fig. 13 km respectively the better Q-factor is done with power equal to 10 and dispersion 4 here

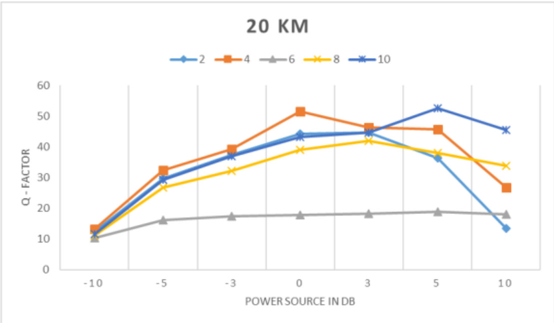

Fig. 8. the Q-factor of different dispersion and power in 20 km

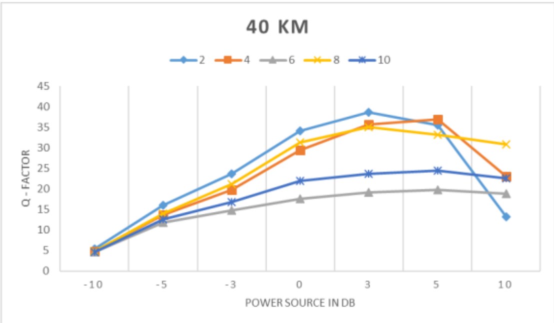

Fig. 9. The Q-factor of different dispersion and power in 40 km

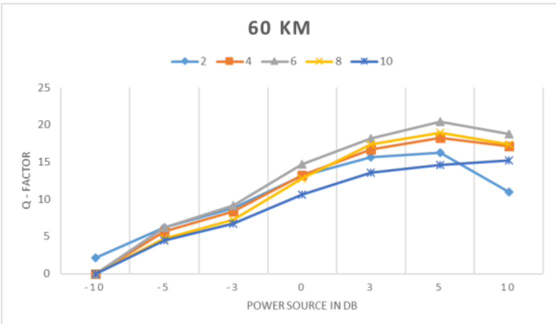

Fig. 10. The Q-factor of different dispersion and power in 60 km

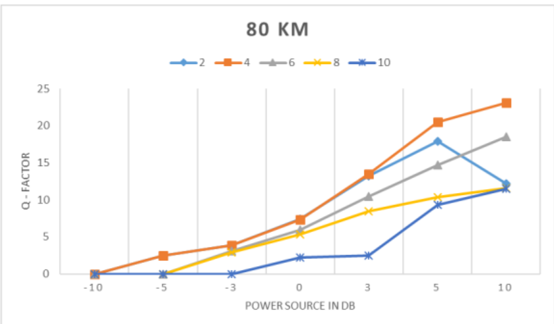

Fig. 11. The Q-factor of different dispersion and power in 80 km

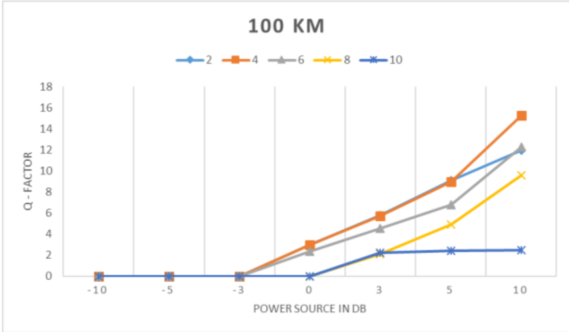

Fig. 12. The Q-factor of different dispersion and power in 100 km

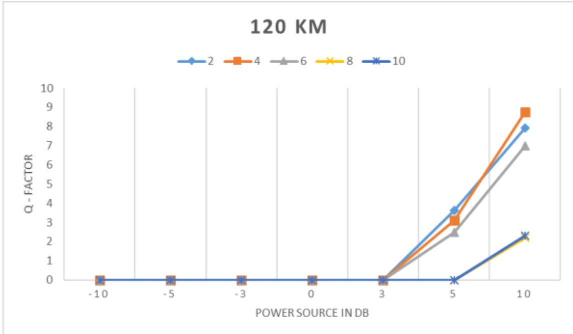

Fig. 13. The Q-factor of different dispersion and power in 120 km

We notice the maximum the power is good for Q-factor in a condition when there is a balance between distance and dispersion. In another word in distance 40 km the better performance done with power not equal to 10 as it supposes but with power equal to 3 and as on for the other distance, so we conclude that the better power in represent in a curve that raise increasingly until it reaches the best performance with specific distance then it decreases, and this maximum point where it reaches is different according to the dispersion and distance.

IV. Conclusions

This paper contains an analyzing investigation of 32 channel - 10 Gbps DWDM-PON FTTH Simulate reaching a village in suburban area in environment that cannot put any sub node (amplifier or repeater) in the middle of the distance, therefore a design has been design that deliver the CO signal directly from the OLT in the central of the city to the houses of the village all the way passive. to accomplish that we used a constant channel Spacing equal 100 GHz. with different power (-10, -5, -3,0,3,5,10) and dispersion (2,4,6,8,10 ps/nm.km), at the end we analysis the BER and Q factor for DWDM-PON in every distance (20,40,60,80,10,120) systems until we reach a maximum distance 129 km with Q factor = 6.16 and BER = 3.44 e-10 in the presence of nonlinearities.

We notice the system is severely limited by dispersion, from previous studies we know that smaller the dispersion and the bigger the power led to better the Q-factor but we prove that not always

- The smaller the dispersion led to better the Q-factor as we see in the figure above in different distance like 80,100,120 km the best

performance is done with dispersion equal to 4 not 2 ps/nm.km as it supposes in the C band that we used.
- The bigger the power led to better Q-factor as was suppose, as we see in the figure above if we draw a curve that represent the raise signal increasingly until it reaches the best performance with specific distance then it decreases, and this maximum point where it reaches is different according to the dispersion and distance.

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