A New Hybrid Architecture of Radio over Fiber/Wavelength Division Multiplexing in Optical Network

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***Abstract*— Now days, there has been a growing and continuous demand for (high data rates) beyond existing wired and wireless networks. Radio-over-Fiber technology is considered as an efficient and practical solution for providing (broadband wireless access). in this paper, many techniques are used to implement a system that has the facility to offer a (high bit rate), (broadband bandwidth), (more coverage), and (lower cost). So, (RoF) technology was used to transmission signals. Wavelength-Division-Multiplexing (WDM) technique was used to send many signals through the same link, and (DFSK) with Non-Return-to-Zero (NRZ) as modulation format. 80Gpbs separate on two channels was transmitted on (Single-Mode-fiber). The average results obtained from our experience were as follows Max Q- factor = 5.775719, Minimum BER = 3.64*10-6, Total Output Power (dBm) = -27.524, OSNR (dB) = 33.58116 for channel_1, for channel_2 Max Q- factor = 6.098659, Minimum BER = 8.70*10-10, Total Output Power (dBm) = -27.592, OSNR (dB) = 33.88505. All the average result that has from our simulation was very good and acceptable. The simulation and performance test of our experience was done using Optisystem.**

Keywords— RoF, WDM, SMF, DFSK, NRZ.

I. MOTIVATION

Optical communication is a style of communication that uses light source as a transmission medium. The radio frequency (RF) spectrum is crowded, and the providing of broadband services in new bands has become increasingly difficult. (RoF) is a representative optical link for the transmission of information via optical fibers by sending (RF) signals from and to the central station to the base station [1].

Nowadays, due to the different requirements of users of the system, the data capacity of wireless communication has been completely widened from simple sounds and messages to multimedia with evolutional future services. RoF technique can be the solution to many of the urgent needs of telecommunication networks, as they can provide the bandwidth required for the transfer of broadband data to end users, and other advantages are little attenuation loss and immunity to radio-frequency-interference [2, 3]. In the (RoF) system, most signals processing processes (‘including encryption’, ‘multiplexing’ and ‘R.F’ generation and modulation) is performed by the central-office (CO), making the base-station (BS) cost-effective. Therefore, (RoF) will turn out to be a key and important tools in the next and future generation of (mobile communications system) [4].

The goal of this work is to enhance (RoF) system the performance by using (DFSK) as a modulation format and (CW) as a leaser source. Also, to increase the input signal on the same cable by using (WDM) technique. Also, the broadband system will be increased by overcoming on many problems that directly effect on the efficiency of system performance, such as the (nonlinear problems) and to compose the architecture (flexible) by using a few components.

Hong and Et. al. [5], have been also proposed a medium access control procedure that has the fast handover feature and has the dynamic bandwidth allocation properties by using the ability of centralized control of radio over fiber networks. The Sandeep and et. al. [6] they are proposed and simulated a full-duplex data and video signal transmission over single-mode fiber (SMF) based on wavelength-division-multiplexing (WDM) and an optical add-drop multiplexing (OADM) technique. The authors Ajay and Navneet [7] have been tried to enhance communication performance. The technologies represented by (RoF), the microwave and optical communication combinations have been provided the unmetered access for the broadband wireless communications. The researchers Arya and Anisha, [8] have been introducing the RoF method together with the full duplex transmission links connected with the (WDM) over the single mode fiber. Other researchers (Amandeep, and et. al., [9]) tried to increase the performance of the RF signal processing services at the head end. Therefore, the complex (BSs) is greatly decreased by executing the optoelectronic amplification functions and conversion (WDM).

Wavelength-Division-Multiplexing (WDM) is a passive device that combines light signals of various wavelengths, coming from various fibers, onto one fiber. These take account of Dense-Wavelength-Division-Multiplexers (DWDM) devices, which use optical (analog) multiplexing techniques to growing the fiber network

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capacity beyond the levels achievable through Time-Division-Multiplexing (TDM). The use of (WDM) for the division of (RoF) signals as shown in Figure-1 has recently gained importance. (WDM) can effectively exploit the bandwidth of the fiber network. These systems could realize capacities more than (1Tb/s) on one fiber. Thereby, single-channel bit rates have increased to (10Gb/s) and systems that operate on (40 Gigabit/s) are commercially available. The channel spacing in (WDM) can be reduced to (50GHz) or even (25GHz), so hundreds of channels can be used. However, if channel spacing has been dropped to (50GHz) instead of (100GHz), it will be very difficult to upgrade systems to operate at (40Gb/s) due to (nonlinear effects) [10]. Figure 1 is shows for us the (WDM) technique. As shown in figure we can send multiple signal over same cable by using (WDM) technique. Every signal has different wavelength. They are combined at transmitter side by multiplexing and send them through transmission medium then finally at receiver side de-multiplexing the signals.

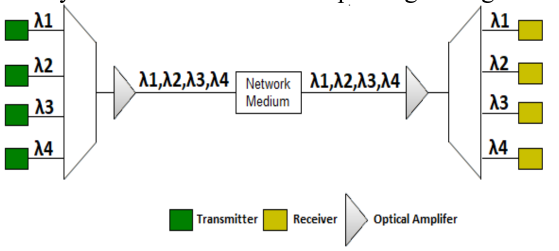

Fig. 1. Wavelength-Division-Multiplexing (WDM) technique

II. RADIO-OVER-FIBER TECHNOLOGY (RoF)

(RoF) is Indicates for a technology, when modulating the light signal with the radio signal and transmitting it through an optical fiber for distributing radio signals from central location (Head-end) to remote-antenna-unit (RAU) [11]. (RoF) is considered an integration of wireless and optical fiber networks, it is a key technology for providing unlimited contact to broadband wireless communications, also for the extension of current wireless coverage and capacity [12] [13].

A. Architecture Design

This architecture consists of five sub-systems as (2 transmitters, 2 receivers, transmission link). The bandwidth of this system is (40Gbps) equivalent to (80Gbps) for two channels. By utilizing the following subsection, we demonstrate each of them in details: each transmitter consists of many components Figure (2), the pseudo random bit sequence generator (PRBSG) used for generating the random seeds of the bit. After that, these bits entered precoder for taking some delay before launched to non-return-to-zero (NRZ).

The behavior model illustrated in Eq. (1), that is in charge for generating an electrical signal to forked into two ways of the input. The LiNb Mach Zehender used to modulate the electrical signal with an optical signal produced by the continuous wave (CW) laser with a wavelength of (1552.52nm) or frequency of (193.1THz) to achieve a fine output. We optimize the input power ten times (1mW to 10mW), as the electronic devises properties we try to show an optimization on these values to exclude the best value, by the way of the LiNb MZ output as an optical signal. It is entered to the second one of LiNb MZ for modulating it with the sine signal (Radio Frequency) which has been generating by sine generator that will be gained by the electrical gain equal to (1).

The output signals from the MZ modulator channel_1 (193.1THz), and channel_2 (193.2THz) are considered as inputs to the WDM (2×1) with its properties (bandwidth=40GHz, depth=100dB, filter type of Bessel, and filter order equal to 2).

The output signals are entered to the loop control with an iteration of 6 and then launched to the transmission link subsystem as showing in Figure (3). That consists of the (two spans of SSMF 25km of length for each, with, three EDFA with gain=5dB, and noise figure=6dB). These amplifiers utilized for amplifying the signals (pre-amplifier, In-line amplifier, and post amplifier). The DCF components are very important because it provides dispersion compensation which occurs through the signal journey, then the signal back to the loop control before entering to the de-multiplexer (1×2), to isolate each input signal at the output channel. At finally, the receiver side as demonstrate in Figure (4) consists of two sub-systems, each of them consist of (MZ) interferometer operate as tunable filter and coupler, and it has 2-inputs and 2-outputs ports, the output optical signal goes to two Photodetectors of type positive intrinsic negative PIN to convert it from an optical to an electrical, and each outputs entering to the electrical subtractor and filtered by the low pass filter with cutoff frequency=$3.2*10^{10}$ Hz, regenerated it by the 3R to reshape and amplified to monitored by the BER analyzer. Eq. (1) is known as Non-Return-to-Zero (NRZ) [14].

$$E(t)=\begin{cases} 1-e^{-(t/c_r)}, 0 \le t < T1 \\ 1, T1 \le T < T2 \\ E^{-(T/c_f)}, T2 \le T < T \end{cases} \quad \dots (1)$$

Where c_r is the rise time coefficient, c_f is the fall time coefficient, $t1$, and $t2$, together with c_r and c_f , are numerically determined to generate pulses with the exact values of the parameters (Rise-time), (fall time) and T is the bit period

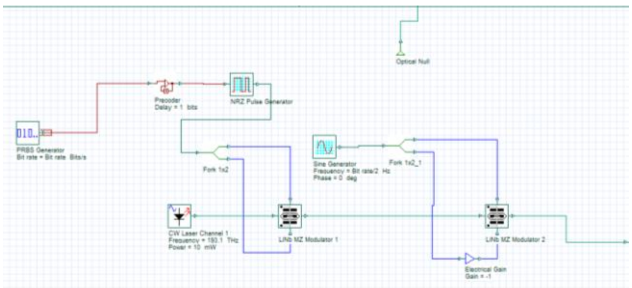

Fig. 2. The Transmitter Components

In this experience we have two transmitter channel. Both transmitters have the same component, Figure (2) shows the components of one transmitter, each transmitter consists from many components, the pseudo-random bit sequence generator (PRBSG) used for generating the random seeds of the bit. After that, these bits entered precoder for taking some delay before launched to non-return-to-zero (NRZ), that is in charge for produce an electrical signal to forked into two ways of the input. The LiNb Mach Zehender used to modulate the electrical signal with an optical signal produced by the continuous wave (CW) laser with a wavelength of (1552.52nm) or frequency of (193.1THz), by the way of the LiNb MZ output as an optical signal. It is entered to the second one of LiNb MZ for modulating it with the sine signal (Radio Frequency) which has been generating by sine generator

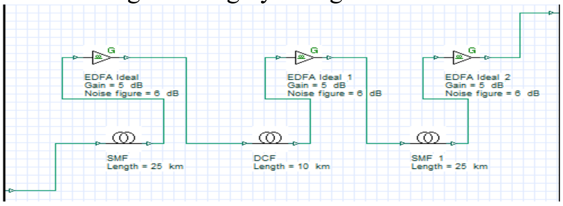

Fig. 3. Transmission Link Components

While figure (3) demonstrates the transmission link subsystem, it is consisting of the (two spans of SSMF 25km of length for each), and three Erbium-Doped Fiber Amplifier (EDFA). These amplifiers utilized for amplifying the signals (pre-amplifier, In-line amplifier, and post amplifier). Using the Dispersion-compensating -fiber (DCF) components are very important because it provides dispersion compensation which occurs through the signal journey, then the signal back to the loop control before entering to the de-multiplexer (1×2), to isolate each input signal at the output channel.

The properties of SSMF are (wavelength reference is 1550nm, length is 25km, attenuation is 0.2dB/km, dispersion is 17ps/nm/km, and dispersion slope is 0.075 ps/nm^2/km). So, the (DCF) components is very important because it is providing dispersion compensation which occurs through the signal journey with their properties of (wavelength reference is 1550nm, length is 10km, attenuation is 0.5dB/km, dispersion is -85ps/nm/km, and dispersion slope is -0.3ps/nm^2/km). Figure (4) shows receivers side in our scheme we have

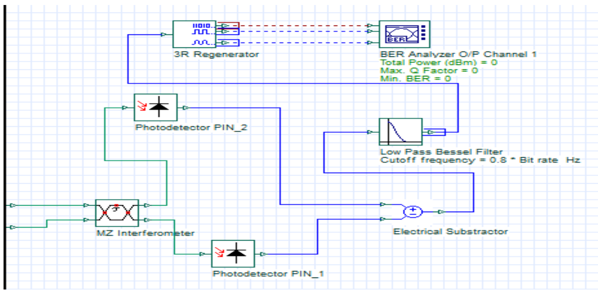

Fig. 4. Optical Receiver Components.

Two receivers, they have the same components, each of them consists of (MZ) interferometer operate as tunable filter and coupler, and it has 2-inputs and 2-outputs ports, the output optical signal goes to two Photodetectors of type positive intrinsic negative PIN to convert it from an optical to an electrical, and each outputs entering to the electrical subtractor and filtered by the low pass filter with cutoff frequency=3.2*10^{10} Hz. Finally regenerated it by the 3R to reshape and amplified to monitored by the BER analyzer:

B. Experiment Results

We will show The results that obtained depending on the software simulation which is used in many iterations and optimizations. Different techniques and approaches are used to reach to best results. Amplitude phase shift keying with two inputs WDM over 60Km SSMF which is utilized to obtain the best outputs in the RoF system. The results in the output explained in Fig (5) - Fig (11).

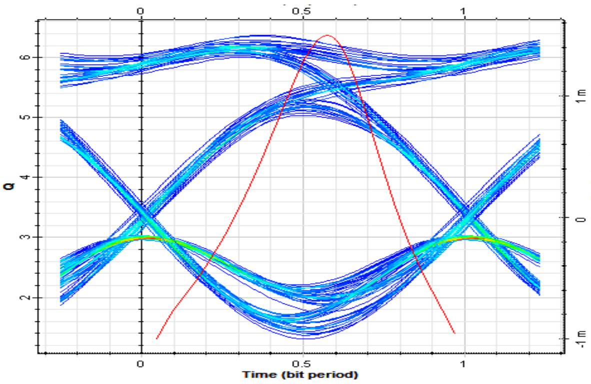

Fig. 5. Illustrate The Q-Factor Vs. Time Vs. Amplitude For The Output Signal On The First Channel, At 60Km SSMF, And 2×40Gb/S Bitrate.

The good eye opening shows in Fig 5 for a data rate of 80 Gb/s over optical fiber length equal 60km, the received signals at the received side is well and demonstrate there are no ISI, and no crosstalk. The x-axis shows the values of the bit period (the intervals between transmitted bit), The bit time refers to ellipse time to one bit to be out from the network, while the amplitude measures the change over the single carrier, and the Q indicates the value Q-factor the high peak in the red color curve show the Q-Factor at this iteration.

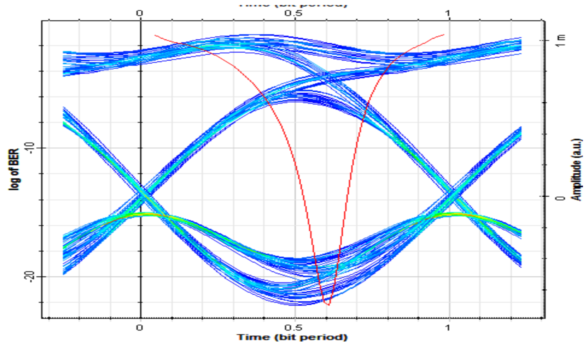

Fig. 6. Demonstrate The Log Of BER Versus And Time Versus Amplitude At The Output Signal Of (193.1thz), At 60Km SSMF, And 2 × 40 GB/S Bitrate.

Fig. 6 demonstrates the eye opening for a data rate of 80 Gb/s over optical fiber length equal 60km, the previous fig shows a good eye opening of the received signals at the received side is well and demonstrate there are no ISI, and no crosstalk. The x-axis shows the values of the bit period (the intervals between transmitted bit), the amplitude is an indicate the changing in period, and the Log of BER indicate the value of BER, the high peak in the red color curve show the Log of BER at this iteration.

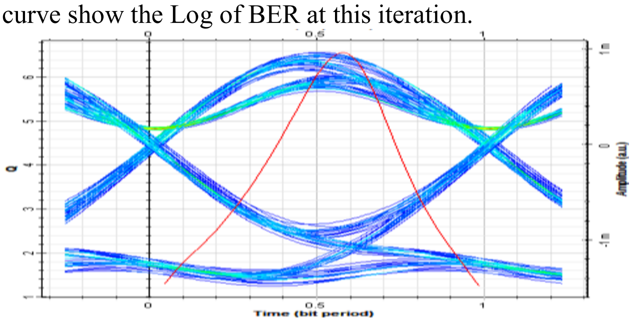

Fig. 7. Shown The Q-Factor Versus And Time Versus Amplitude To The Output Signal For Channel_2, At 60Km SSMF, And 2 × 40 GB/S Bitrate.

The good eye opening shows in Fig 7 for the second channel, when the data rate equal 80 Gb/s over optical fiber length equal 60km, the received signals at the received side is well and demonstrate there are no ISI, and no crosstalk. The x-axis shows the values of the bit period (the intervals between transmitted bit), The bit time refers to ellipse time to one bit to be out from the network, while the amplitude measures the change over the single carrier, and the Q indicates the value Q-factor the high peak in the red color curve show the Q-Factor at this iteration.

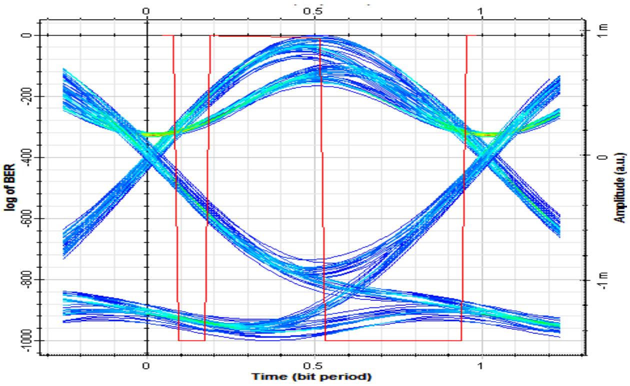

Fig. 8. Demonstrate The Log Of BER Versus And Time Versus Amplitude To The Output Signal Of (193.2thz), At 60Km SSMF, And 2 × 40 GB/S Bitrate.

Fig. 8 demonstrates the eye opening for a data rate of 80 Gb/s over optical fiber length equal 60km, the previous Fig shows a good eye opening of the received signals at the received side is well and demonstrate there are no ISI, and no crosstalk.

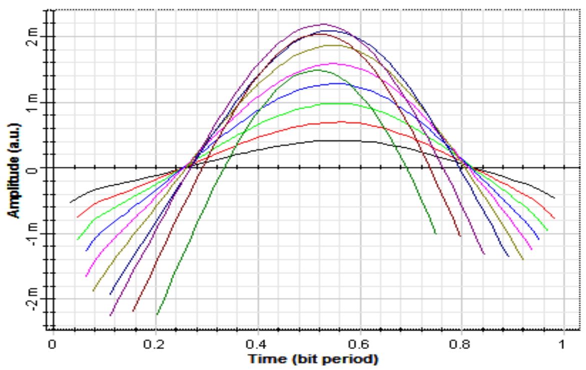

Fig. 9. Eye Amplitude Versus Time For Ten Iterations (The Light Green, Red, And Black Colors Show The Worst Iterations), @60Km SSMF, And 2×40Gb/S Bitrate.

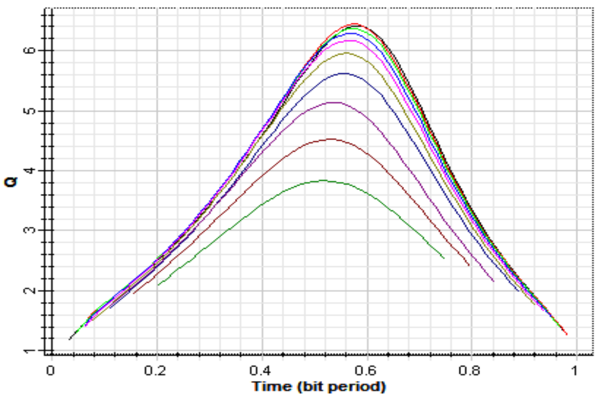

Fig. 10. Show The Q-Factor From The Output For All Iterations, @60Km SSMF, And 2×40Gb/S Bitrate.

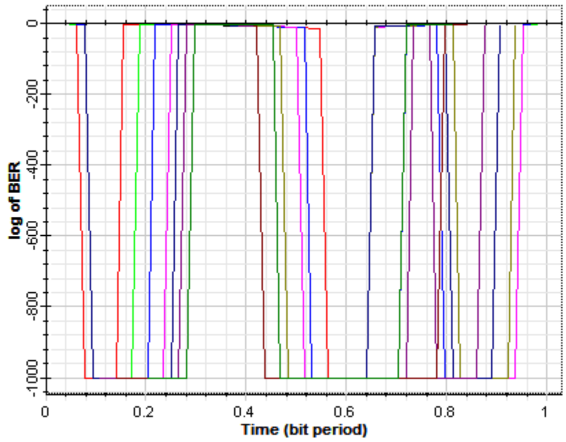

Fig. 11. Minimum BER For All Iterations Shows The Log Of BER Vs. Time, @60Km SSMF, And 2×40Gb/S Bitrate.

The last three figures (9-11) are shows all iterations at one figure, each iteration has a different color. In figure (9) we can show the eye Amplitude versus time for all iterations, for the second figure the Q-factor is clear for all iteration. While at last figure the log of BER versus Time is showing for all iterations.

The best iteration can be obtained when the input power of two channels are (1, 1.6, 2.3, 3.1, 3.9, and 5.9 dBm) respectively. The reasons for this due to selecting an optimum values for parameters in each components of our simulation. However, if the input powers are (4.8, 5.9,7, 8.4, and 10dBm), there is no output on the second channel at the receiver side because of the fiber nonlinearity caused from the interference between symbols. The Figures from (5.9) to (5.18) show some important values of total power of the input, maximum Q-factor, minimum BER value, total power of the output, and OSNR value of first and second channels.

C. Analysis The Result

Practically, the figures above give a good result in the system outputs as radio over fiber based on differential phase shift keying modulation format. In this experiment, DFSK is a modulation type, CW is a laser light source, many parameters were used on the transmitter and receiver side, WDM was used for exploit the optical cable by sending many channels on the same cable. Many improvements have been done on (power) to reach the best possible result, in the end, the transmission of 40GHZ per channel was achieved along a distance of 60KM. This means that in the totally (80GHz) has been sent over 60KM. The average results obtained from our experience were as follows. The average power of the input is (4.8dBm), the average of maximum Q factor value is (5.775719), the average of minimum BER value is ($3.64*10^{-6}$), the total average power of the output is (-27.524), and the average value of the OSNR is (33.58116dB) for the first signal. While at the second signal, the average power value in the input is (4.8dBm), the maximum average value of the Q-factor is (6.098659), the minimum average value of the BER is ($8.7*10^{-10}$), the total average value of the power in the output is (-27.592dBm), and the average of OSNR is (33.88505dB)), the result of the work is very acceptable because of the compatibility of the components and the parameters with each other.

III. CONCLUSION

Nowadays, RoF communication system has drawn much attention. The architecture of RoF has various components (active component and passive component). The optimization on input power also was be done by using the simulation of the Optisystem application which is provided by the Canadian company. This article, architecture a RoF /WDM with DPSK modulation based on SSMF. In this work, the oscilloscope and BER analyzer are used to monitor the behavior of the signal. The experience works split into two parts (the first and second signals). In the first signal, the result was as the following: input power average was (4.8dBm), maximum Q factor average was (5.775719), minimum BER average was ($3.64*10^{-6}$), total power average of the output was (-27.524), and the OSNR average was (33.58116dB). In the second signal, the result was as the following: input power average was (4.8dBm), maximum Q factor average was (6.098659), minimum BER average was ($8.7*10^{-10}$), total power average of the output was (-27.592dBm), and the OSNR average was (33.88505dB). There is some ISI appears in the previous architecture because of the nonlinearities properties in the fiber phenomena and the second reason is the distance of the fiber span is very long. All the average values are good and acceptable, we get on it because we using an attractive component and there is compatibility between all components. The simulation and performance test of RoF was done using Optisystem 7.0.

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