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The Impact of Switching Voltage of the Mach-Zehnder Modulator on a Subcarrier Multiplexing Amplitude Shift Keying Radio over Fiber System

A B S T R A C T

Radio over Fiber technology (ROF) is an essential technology for saving the remote access to broadband wireless communication. It is a combination of wireless and fiber optic networks. In this research the influence of changing the switching voltage of Mach-Zehnder modulator on millimeter wave ROF system has been presented. One of an important known data modulation as subcarrier multiplexing amplitude shift keying SCM ASK was examined. Eye diagrams were used to effectively analyze the performance of ROF optical system at different switching voltages. A larger "eye opening" signifies less noise or distortion and therefore a higher quality of the received signal. The simulation analysis shows that there are an exist acne of an optimum switching voltage (8v). The software package called "Optisystem ver. 12" has been utilized to simulate this system.

تأثير تغير الجهد على تقنيه تضمين أزاحه السعه ومضاعفه الناقل لراديو عبر الألياف

الخلاصة

تقنية الراديو عبر الألياف (ROF) هو عبارة عن تقنية ضرورية لتوفير الوصول البعيد إلى النطاق العريض فى الاتصالات اللاسلكية وهذه التقنية مزيج من الشبكات اللاسلكية والألياف الضوئية. في هذا البحث تم دراسة تأثير تغيير الجهد فى المضمن ماخ زيندر على الموجات الإذاعية عبر نظام الألياف (ROF). وفي هذا البحث، أحد البيانات الهامة للتعديل هي فحص مضاعفة تحول السعة SCM ASK. أن اشكال العين تم استخدامها للتحليل الفعال لأداء نظام (ROF) حيث ان سعة شكل العين تدل على ضوضاء وتشويش أقل ولهذا السبب تم اختيار الـ8 فولت هي الفولتية الامثل لتحسين أداء هذا النظام. وقد تم استخدام حزمة البرامج التي تدعى "Optisystem Ver.12" لتطبيق هذا النظام.

1. INTRODUCTION

Fiber optic communication is a communication innovation that utilizes light pluses to transfer a data starting from one point to the next one through an optical fiber. The transmitted data is basically a digital data that created by telephone system, satellite TV organizations, and PC systems [1].

Nowadays a wide demand of bandwidth for wireless and wired communication have been observed with the coming bandwidth of imperative applications, like video based reactive and multimedia services. The limitation of the frequency spectrum and the congestion of the current wireless system are a restricted the data rates to be a Megabits-per-second (Mbps) only. In addition to that, the most affirmed way to gigabits-per-second (Gbps) is the utilization of the millimeter wave frequencies which possesses wide bands of frequency spectrum [2].

2. PRINCIPLE OF MM-WAVE ROF

Radio over fiber (ROF) or RF over fiber (RFOF) refers to a technology whereby light is a modulated by a radio frequency signal and that transmitted over an optical fiber link. Main technical advantages of using the fiber

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optical links are lower transmission losses, noise sensitivity reduction, and less electromagnetic interference compared with the electromagnetic signal transmission [3].

A basic structure of the ROF system is shown in Fig. 1. In the downlink transmission, the laser diode is modulated directly with RF signals and the results are intensity modulation for optical signals. After that, the optical signals have been transmitted through an optical fiber to the base station. At the Base Station, a photo-diode is applied to the direct demodulation on the optical signals for retrieving the RF signals. Moreover, they are amplified and radiated by an antenna [4]. ROF technology is known as intensity modulation and direct-detection based on a modulation and detection. The opposite process is executed at the Base Station. RF signal or digital data is directly modulating the laser drive current in a direct optical modulation. This method of modulation is widely used in the fiber optic links due to its simplicity and cost effectiveness.

The resulting optical signals are transmitted through an optical fiber to the central station [5]. At the central station, the intensity of the of the modulated optical signals are demodulated and directly employing a Photo Detector to recover the data. Thereafter, the signals are amplified and processed. The essential structure of ROF system comprises of central station and remote access unit (RAU) that associated by a single mode fiber. Radio over fiber shows many benefits like:

- Wide bandwidth
- Low attenuation loss
- Inviolability to radio frequency interference [6]

Basic structure of Lithium Niobate Mach-Zehnder Modulator. The Mach-Zehnder structure consists of an input optical section, which divides the incoming light into two branches, followed by two independent optical branches, which are recombined by the output optical branch. Utilization of an electrical signal to one of the optical arms controls the obstruction level at the output optical branch and along these lines the output intensity is controlled [6]. The optical field at the modulator output is given by Eq. (1):

$$E_0 = \frac{E_{in}(t)}{10^{\left(insertion\frac{loss}{20}\right)}} \cdot \left(\gamma \cdot e^{\left(j.\pi.v_{2(t)} \cdot \frac{1}{V_{\pi RF} + J.\pi.} v_{bias2}/V_{\pi DC}\right)} + (1-\gamma) \cdot e^{\frac{i.\pi.v_{1(t)} \cdot \frac{1}{V_{\pi RF} + J.\pi.} v_{bias1}/V_{\pi DC}}}\right) \tag{1}$$

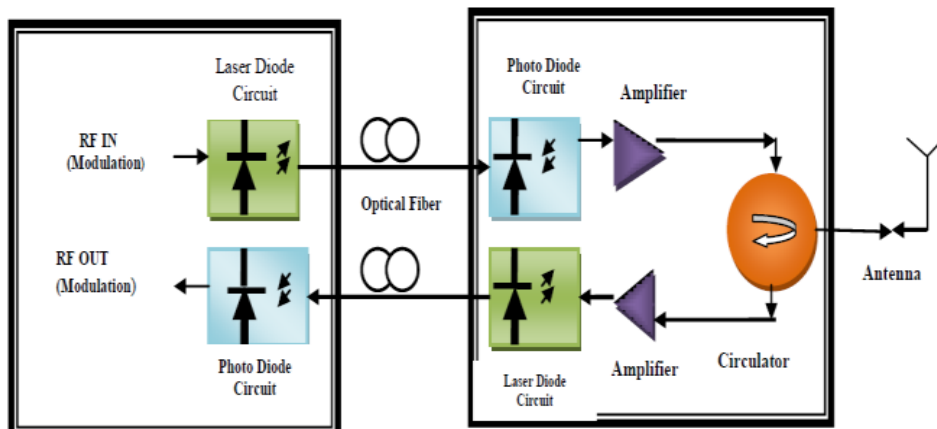**Fig. 1.** The essential structure of the radio over fiber system [7].

where
$E_r = 10^{(Extratio/10)}$
$E_{in}(t)$ is the input signal.
ε_r is the effective drive field.
$v_1(t)$ and $v_2(t)$ are the RF modulating electrical voltage.
v_{hias1} and v_{hias2} are the DC Bias voltage that applied on arms No.1 and No.2 respectively.
v_{RF} is the switching RF voltage.
$v_{\pi DC}$ is the switching DC voltage.

Here γ denotes the power that supporting (joining) the ration of branch two for the input and output, respectively Y-arm waveguide, which is given by:

$$\gamma = \frac{\left(1 - \frac{1}{\sqrt{\varepsilon_r}}\right)}{2} \tag{2}$$

If the Switching bias voltage is equal to the Switching RF Voltage, and the normalize electrical signal parameter is False, the bias voltage can be included in the electrical signal.

The optical power and phase of the modulator output are determined in response to the modulating voltage waveforms. The modulator transfer function relates the effective drive voltage to the applied drive voltage [7].

3. SIMULATION AND DISCUSSION

The effectiveness of the switching RF voltage of MZM on system performance in the SCM ASK Radio over fiber has been studied and simulation computations have been performed for the four basic distinctive switching voltages by utilizing the commercial programming package known as Opti-System [8].

In this paper the effect of the modulation voltage on the SCM ASK ROF will be analyzed. The principle diagram of the transmitter side of the simulation set up of ROF is shown in the Fig. 2. Non-return to-zero (NRZ) information signal was modulated at 1550 nm wavelength for optical carrier and sideband in the meantime, and mixed up recognition was used to finish straightforward and simple receiver.

The framework parameters of the simulation set up is sketched out in Table 1. The attenuation of single mode fibre SMF has been compensated by Erbium Doped Fibre Amplifier EDFA and the ideal LiNb MZM Modulator was used. The receiver side of the simulation set up of ROF system is shown in Fig. 3.

The transmission distance of the distribution system is 10Km over a Single Mode Fiber link and 1550 nm wavelength, the most extreme Q factor versus Eye opening in the conventional subcarrier multiplexing Amplitude Shift Keying SCM ASK ROF connection is shown in Fig. 4. It is observed that most the extreme *Q* factor differs with the switching RF voltage of MZM, and an optimum modulation voltage is (8V) compared with the ideal system execution (Q factor= 9.12) maximum eye opening is 0.00042.

The transmission distance is 10Km over a single mode fiber link for the distribution system. The most extreme Q factor versus time bit period in the enhanced SCM ROF connection is shown in Fig. 5. The eye diagram represents an overlap of all bits in the signal on top of each other. There are two basic types of negative effects obvious in the

eye diagrams: Firstly, the impact of inter-symbol interference (ISI) and, secondly, the effect of jitter [8]. The ISI is caused by the superposition of the individual modulation pulses and it leads to an amplitude error at the sampling patterns. The jitter is defined as short-time deviation of a digital signal from its ideal position in time. A larger "eye opening" means less noise or distortion and therefore a higher quality of signal [8]. Fig. 6 illustrates the relation between the time periods (bit periods) of ROF system versus the eye opening.

The eye diagrams of enhanced ASK SCM Radio over Fiber with various modulation voltages (8v, 16v, 20v, and 30v) are shown in Figs. 7-10, respectively. It can be seen that the eye opening was clear and evident although when the modulation voltage reaches roughly 20v. However, the eye diagram becomes unclear when the switching voltage reached 30 v. This means the system performance is poor as it is not possible to get an acceptable BER reading and the eye diagrams looks ''messy'' with severe distortion at zero crossing.

From the simulation results shown in the Table 2 it is found that the optimum system performance is obtained when the modulation voltage is 8v. This is clear in Fig. 7 which shows the eye diagram when the switching modulation voltage is 8 v.

It can be seen that the eye opening is 0.00042 wide and there is no cross talk in the eye since there is no time jitter at the edges of the eye. Thus eye diagrams can be used to effectively analyze the performance of an optical system.

A larger "eye opening" signifies less noise or distortion and therefore a higher quality of signal and the quality factor is approximately is 9.12. Whereas when the switching modulation voltage is 30 v the system performance is ineffective as it is not possible to get an acceptable BER reading and the eye diagrams looks ''messy'' with severe distortion at zero crossing as shown in Fig. 7. The eye opening will be small and thus effectively reducing the system performance. Eye diagrams clearly depict the data handling capacity of a system.
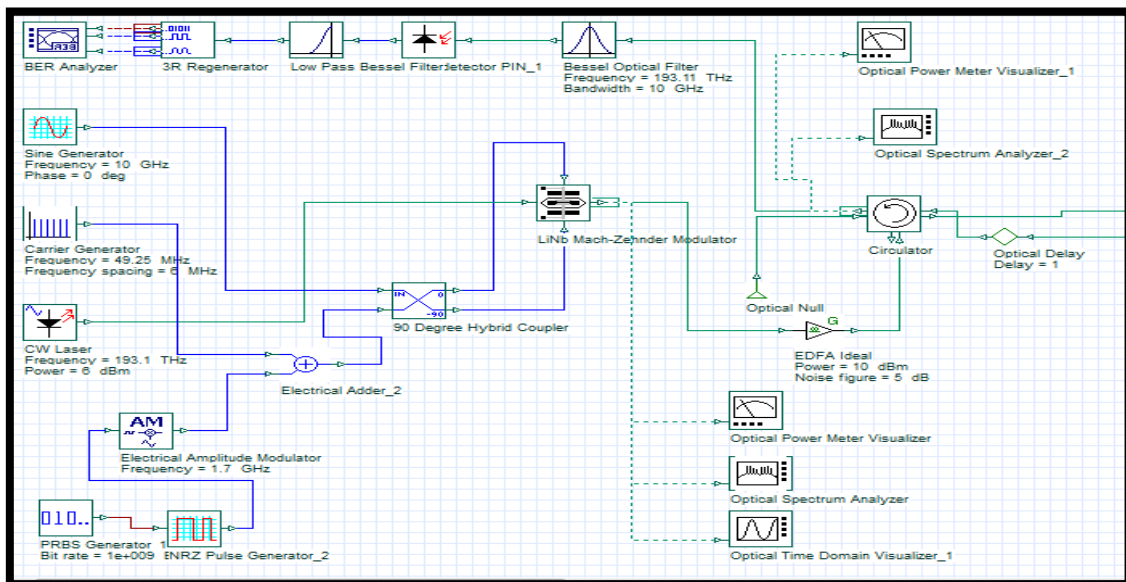

Fig. 2. Simulation setup of the transmitter side ROF system.

Table 1
Simulation parameters of the SCM ASK RoF system.

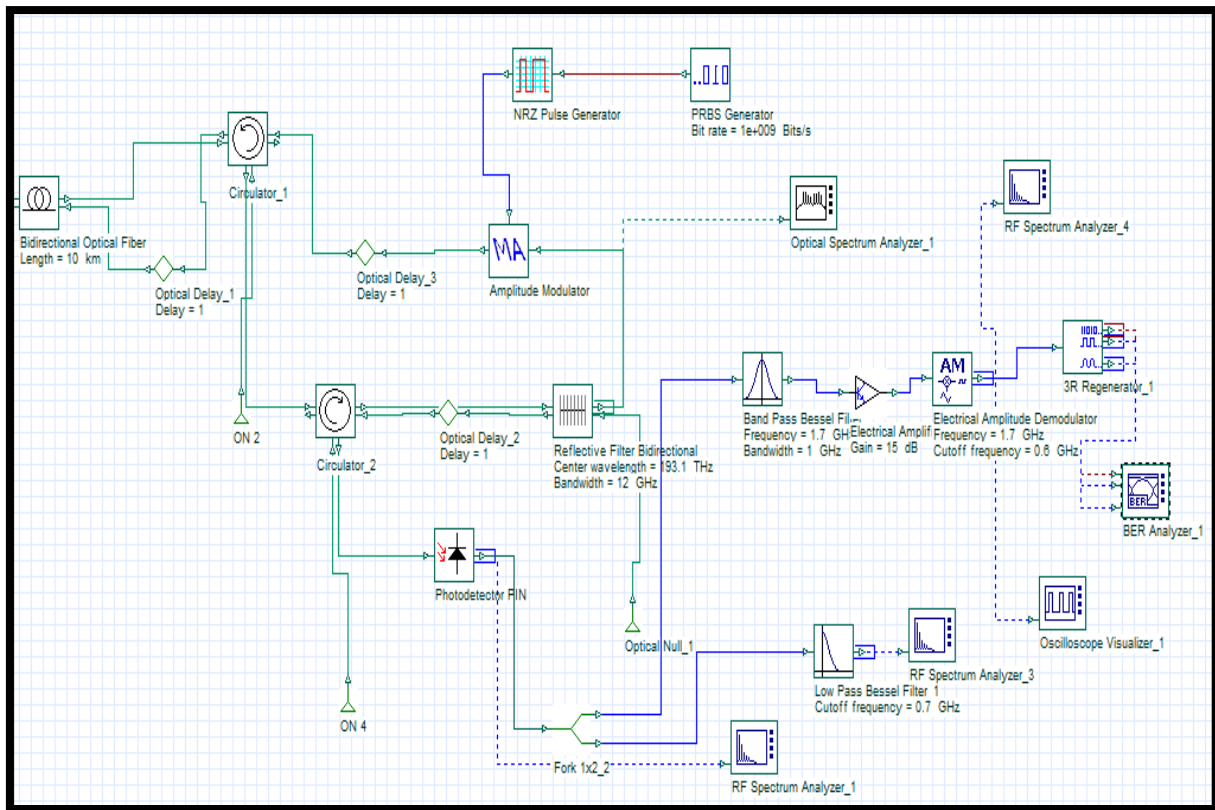| Parameter	Value	Parameter	Value
Bit rate of optical channel	10 Gbit/s	fiber dispersion	16.75 ps/nm/km
The center frequency of LD	193.1 THz	Responsivity of PD	1 A/W
bandwidth of LD	10MHz	center wavelength of (BPF)	1.7 GHz
RF frequency	1.7 GHz	Fiber length	10KM
switching voltage of MZM	8 - 30v	SMF wavelength	1550 nm

Fig. 3. Simulation setup of the receiver side ROF system.
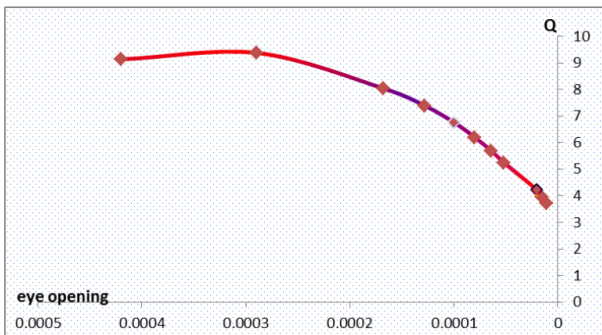

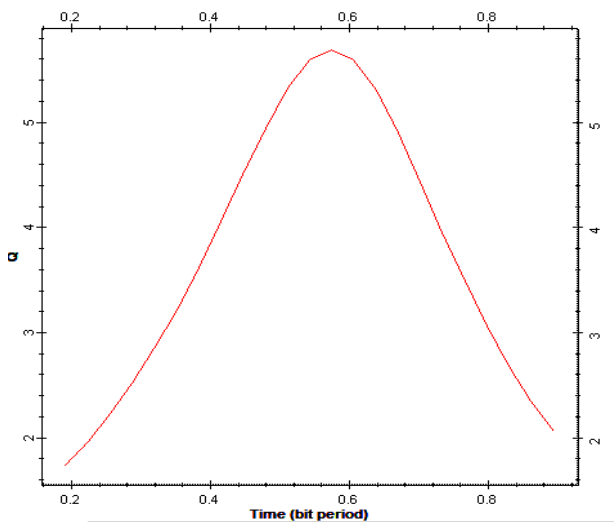**Fig. 4.** Eye opening versus Q factor.

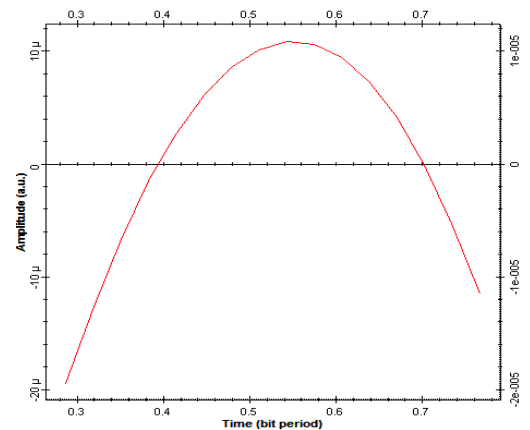**Fig. 5**. The *Q* factor versus the time period.

Fig. 6. The relation between the time period versus the eye opening.
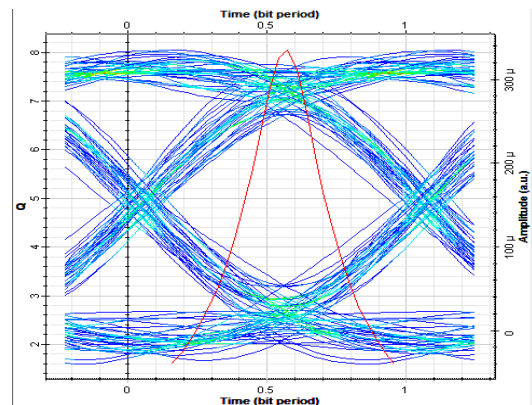

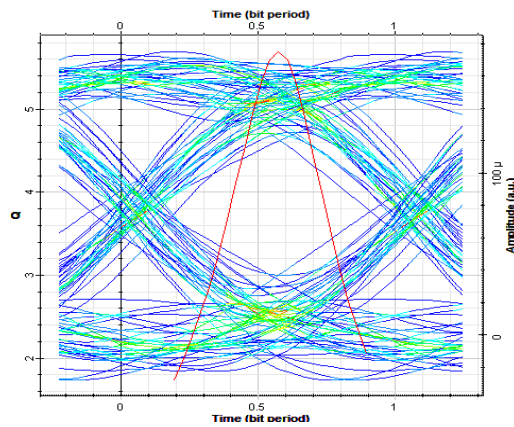**Fig. 7.** Eye digram when switching voltage 8v.

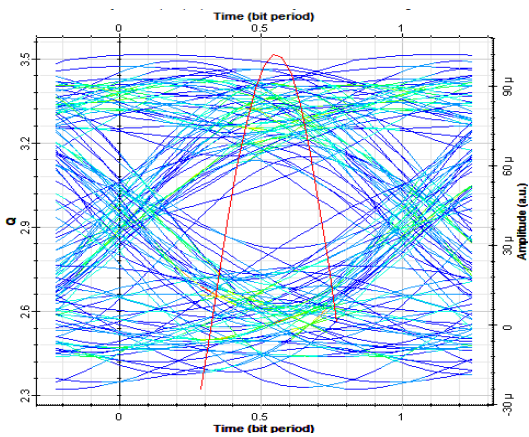**Fig. 8.** Eye digram when switching voltage 16v.

Fig. 9. Eye digram when switching voltage 20v.
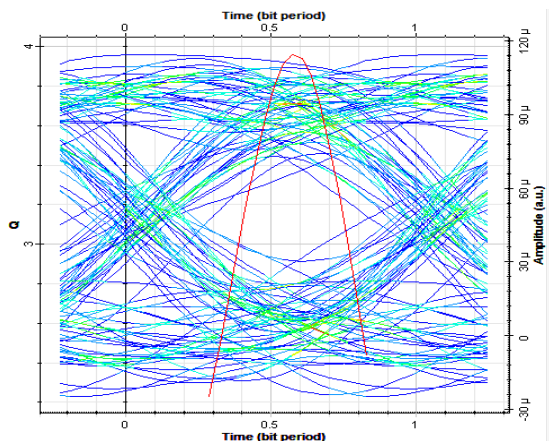

Fig.10. Eye digram when switching voltage 30v.

Table 2
Simulation results of the SCM ASK ROF system.

Modulation voltage(v)	Q factor	Eye height
8	9.120	0.000420
10	9.380	0.000290
12	8.040	0.000168
16	7.380	0.000128
20	6.750	0.000100
22	6.190	8.01×10^{-5}
24	5.689	6.45×10^{-5}
26	5.240	5.21×10^{-5}
28	4.220	2.60×10^{-5}
30	3.950	1.54×10^{-5}

4. CONCLUSIONS

It is concluded that the effect of switching RF voltage of Mach-Zehnder modulator on the performance of SCM ASK Radio over Fiber connection utilizing diverse voltage modulation plan is simulated and analyzed. It is clarified that the practical results were improved by changing the switching voltage of MZM and it is presumed that the greatest Q factor differs with the exchange RF voltage with MZM, and an optimum modulation voltage (8v) relating to best system performance of Q factor is around 8v. In this research the eye diagrams was illustrated at different switching voltage and was unclear when the switching voltage reached 30v because the system performance is ineffective as it is not possible to get an acceptable BER reading and the eye diagrams looks "messy'' with severe distortion at zero crossing. The eye opening will be small thus effectively reducing the system performance. Eye diagrams clearly depict the data handling capacity of the system.

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