Investigation of Modulators in OTDM system

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ABSTRACT
With the ever-increasing demand for higher speeds and larger capacity brought about by rapid data growth on the Internet, interest in optical time division multiplexing has been growing rapidly in recent years due to its high speed and ability to overcome the "electronic bottleneck" offered by today's electronic components. Optical time division multiplexing (OTDM) transmits multiple data channels in the form of ultra-short duration optical pulses which are interleaved into a single high-speed data stream by accurate control of their relative delay in the time domain. OTDM transmission system has been a topic of continuous research due to their unique advantages over conventional Pulse sources based transmissions. Among various key high repetition rate, limited pulse source, pulse range still remains as the issues that require further optimization. The performance of OTDM system is analyzed by using BER analyzer in which Q factor is to be measured. In OTDM system the maximum Q factor can be achieved by using different methods which are increasing laser power, using various.. We will focus on performance metrics and parameters used in the topology. We also focused on various modulators related to the topology.

Keywords
OTDM, BER

1. INTRODUCTION
Although an optical fibre is a very wideband medium for information transmission, practically it is impossible to modulate the full optical bandwidth at once. This is because an optical signal is initially generated from an electrical data pattern and converted back into an electrical signal after transmission for the recovery of the transmitted data [1]. With the ever-increasing demand for higher speeds and larger capacity brought about by rapid data growth on the Internet, interest in optical time division multiplexing has been growing rapidly in recent years due to its high speed and ability to overcome the "electronic bottleneck" offered by today's electronic components. In comparison to Wavelength Division Multiplexing (WDM) where multiplexing occurs in the frequency domain, Optical Time-Division Multiplexing (OTDM) transmits multiple data channels in the form of ultra-short duration optical pulses which are interleaved into a single high-speed data stream by accurate control of their relative delay in the time domain[2]. By using OTDM technique very high capacity of data over optical fiber can be achieved. These type of systems can provides higher speed than electronic components, several technologies are needed to realize in order to achieve higher speed in OTDM systems. These include high repetition rate ultra-short pulse sources, high speed demultiplexing, clock recovery and accurate dispersion compensation. Many of these technologies are still at the research stage, which makes high-speed OTDM currently a relatively expensive transmission solution. Regardless of this, OTDM is still an alternative way to increase the transmission capacity of a fiber system. Compared to conventional WDM transmission systems, it may offer several advantages [2]. In terms of transmission performance, since only one wavelength is used in a pure OTDM system, the gain tilt problem and dispersion tilt problem [3, 4] associated with wide-band WDM transmission can be eliminated. Also, the major limiting nonlinear effects for WDM systems, such as four wave mixing (FWM) and Stimulated Raman scattering (SRS) can be avoided [5].

The basic principle of this technology is to multiplex a number of low bit rate optical channels in time domain as illustrated in Figure 1. At the transmitter side the OTDM all the signals are modulated and then combined by using power combiner in order to travel on the channel. At the receiver, the OTDM signal is separated into original multiple base-rate channels by using power splitter for the BER measurements. OTDM transmission systems require an all-channel independent modulation multiplexer (MUX) and an all-channel simultaneous demultiplexer (DEMUX).

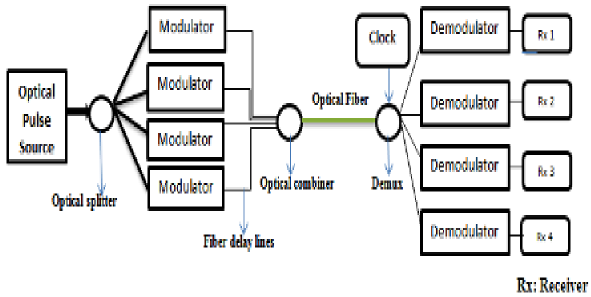

Fig.1: OTDM System

2. MODULATION
The huge quantity of data which is utilizing and transmitting daily for using in internet or when using in telephony is created and processed in the electrical domain. On the other hand, we can take the benefit of using light for processing and transporting this data. By using optical communication one can get long haul and high capacity submarine links (from about 1000 to a couple of 10000's km) [6]. Accordingly, the data originating from a large number of users is multiplexed in time in the electrical domain before being transmitted at a high bit rate over optical fibers.

An important aspect of an optical system is therefore the modulation operation, which is used for converting the high bit-rate electrical data signal into the optical domain. Ideal modulation is therefore equivalent to performing a frequency translation from the baseband to an optical carrier frequency, of the order of 193 THz (i.e., 193×1012 Hz) for the usual

1550 nm transmission window [6]. In this paper I have used the three types of external modulators which are described below.

2.1 Amplitude Modulator

Amplitude modulator is defined as modulation of the signal by varying its amplitude. In this modulator, the optical carrier is modulated externally by the electrical modulation signal. Assuming that the optical input signal is E_{in}, the following equations describe the behaviour of the model.

$$E_{out}(t) = E_{in}(t).\sqrt{(Mod\,(t))} \qquad (1.1)$$

Where E_{out}(t) is the output optical signal and Mod(t) is defined as

$$Mod(t) = (1 - MI) + MI\,.Modulation\,(t) \qquad (1.2)$$

Where MI is the modulation index and modulation (t) is the electrical input signal. The electrical input signal is normalized between 0 and 1[7].

2.2 Mach-Zehnder Modulator

The Mach-Zehnder modulator is an intensity modulator based on an interferometric principle. It consists of two 3 dB couplers which are connected by two waveguides of equal length. By means of an electro-optic effect, an externally applied voltage can be used to vary the refractive indices in the waveguide branches. The different paths can lead to constructive and destructive interference at the output, depending on the applied voltage. Then the output intensity can be modulated according to the voltage[7].

In order to illustrate the principle, we consider the simple interferometric structure represented in Fig.2.1. It is based on a Mach-Zehnder interferometer including one electro-optic material in one of the arms.

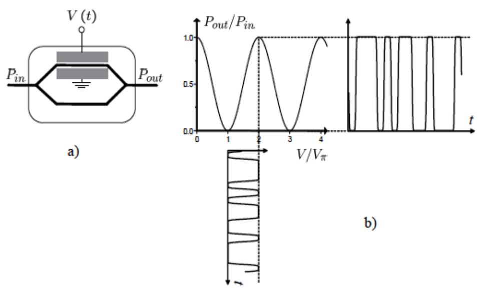

Fig.2: Principle operation of a Mach- Zehnder Modulator.

2.3 Electro-absorption modulator.

This type of modulator relies on the fact that the effective bandgap E_g of a semiconductor material decreases when an external voltage is applied. Consequently, if the frequency of an incoming lightwave is chosen so that its energy E = hv is smaller than the bandgap when no voltage is applied, the material will be transparent. On the other hand, when an external voltage is applied, the effective bandgap will be reduced, meaning that the lightwave will be absorbed by the material when E > E_g[7].

3. PROBLEM DEFINITION

In OTDM system, at the transmitter side Pseudo random bit sequence generator is used. (PRBS) generates the bits according to order mode. Here PRBS generator with order k is used to generate a sequence with period of 2^k-1. The random sequence then fed to RZ pulse generator to produce electrical RZ pulse, generates a return to zero coded signal. Rectangle shape is used to determine the shape of edges of the pulse. According to the parameter Rectangle shape, this model can produce pulses with different edge shapes as Exponential, Gaussian, Linear and sine range which can be used as default value.

In OTDM system, modulator is used both at transmitter side and receiver side. At transmitter side it is used to convert electrical signal to optical signal and at receiver side used as demodulator in order to convert optical signal back to electrical signal for BER measurements.

So, our aim is to investigate the best range of the shape of RZ pulse generator in OTDM system when the different modulators are used. The modulators used in my system are Amplitude modulator, Mach-Zehnder modulator and Electro-absorption modulator. All the three modulators are discussed above.

4. SIMULATION RESULTS AND DISCUSSION

Multiple simulations for AM, MZM and EAM for OTDM system at an optical wavelength of 1550 nm are carried out. The results were analysed using BER analyser in which Q factor is to be evaluated.

The system performance is monitored on the basis of BER analyzer and graphs generated from the BER Analyzer for the following system setups.

The designed OTDM system is used for analysis of different modulators and different pulse shapes of the RZ pulse generator. The main motivation behind this is to find the optimum modulator for which Q factor is greater than or equal to 6 as required by the OFC standard. The system is configured with 4 channels. Using the system simulation setup in the Optisystem9.0 simulator, the value of Q factor is measured by using BER analyzer at the receiver after using different modulators.

Required Q>=6 (as per OFC standard).

At Fiber attenuation = 0 ps/nm/km.

At Laser frequency = 193.1 THz.

At Bit rate = 10 GB/s.

In this paper I have taken into consideration three parts for evaluation.

The different RZ pulse generators used in this setup are Exponential, Gaussian, Linear and Sine.

4.1 Amplitude Modulation with different ranges of RZ pulse generator

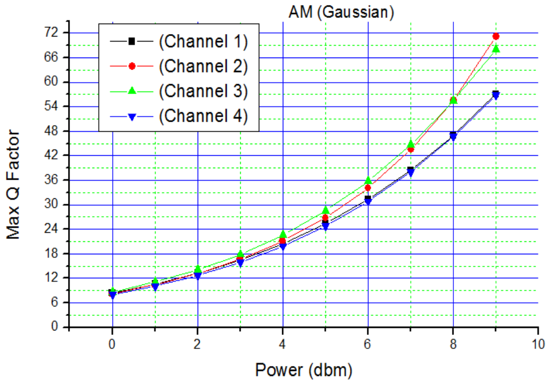

Fig. 3: Max Q Factor verses Power at Gaussian pulse shape of AM.

4.2 Mach- Zehnder Modulation with different ranges of RZ pulse generator

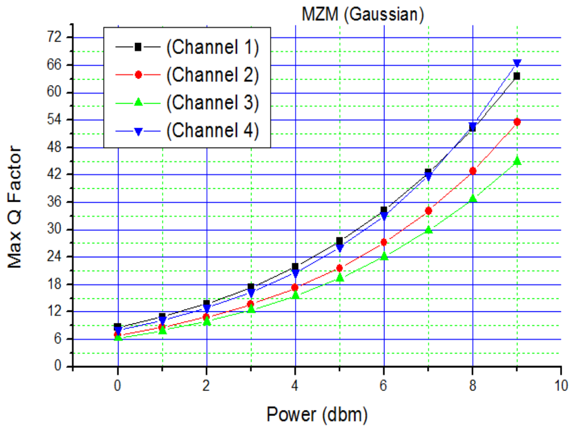

Fig. 4: Max Q Factor verses Power at Gaussian pulse shape of MZM.

4.3 Electro-absorption Modulation with different ranges of RZ pulse generator

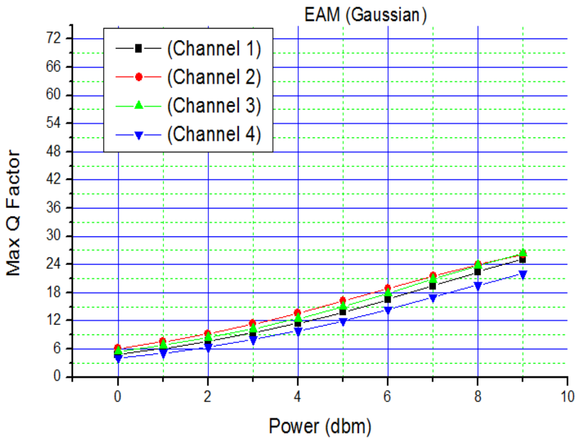

Fig.5: Max Q Factor verses Power at Gaussian pulse shape of EAM.

Table 1: Q.FACTOR VERSUS POWER for Amplitude Modulator

Power in dbm	Channel 1	Channel 2	Channel 2	Channel 4
0	8.44928	8.2109	8.65196	8.03086
1	10.5637	10.386	11.0397	10.0794
2	13.1908	13.144	14.048	12.6442
3	16.4443	16.6471	17.8322	15.8467
4	20.4536	21.1106	22.5763	19.8289
5	25.3623	26.812	28.4881	24.7489
6	31.3207	34.1122	35.7934	30.7709
7	38.4951	43.488	44.7083	38.0657
8	47.023	55.5588	55.4002	46.7174
9	57.0433	71.0656	67.9586	56.812

Table 2: Q.FACTOR VERSUS POWER FOR Mach-zhender Modulator

Power in dbm	Channel 1	Channel 2	Channel 3	Channel 4
0	8.60403	6.81934	6.29243	8.0453
1	10.8932	8.58896	7.89995	10.1819
2	13.7657	10.8183	9.90837	12.8849
3	17.3568	13.6251	12.4079	16.3053
4	21.8303	17.1556	15.5099	20.6338
5	27.3677	21.5885	19.3464	26.1167
6	34.155	27.1386	24.057	33.0525
7	42.3718	34.0748	29.8029	41.811
8	52.1677	42.7112	36.7186	52.8368
9	63.6229	53.4416	44.9183	66.639

Table 3: Q.FACTOR VERSUS POWER FOR Electro-absorption Modulator

Power in dbm	Channel 1	Channel 2	Channel 3	Channel 4
0	4.86434	6.03415	5.47966	4.06213
1	6.08601	7.48788	6.77677	5.10376
2	7.56763	9.23256	8.35106	6.38478
3	9.33771	11.2847	10.2351	7.94294
4	11.424	13.6282	12.4509	9.80257
5	13.8333	16.2022	15.0073	11.9691
6	16.5363	18.8925	17.852	14.3954
7	19.446	21.5432	20.8516	16.9798
8	22.3941	23.9907	23.7865	19.5624
9	25.1499	26.1082	27.3748	21.96

5. CONCLUSION

After analyzing the various evaluated results (Table 1, Table 2, Table 3) and various graphs (Fig.3, Fig.4, Fig.5) we have concluded that keeping the cw laser frequency and bit rate fixed the best performance is achieved for amplitude modulator for Gaussian pulse range of RZ pulse generator.

1. With the increase in power the maximum Q factor increases. For laser power equal to 0 dbm the maximum Q factor is above 6 which is just acceptable in OFC standard.

2. By increasing power upto 9 dbm the maximum Q factor increases.

3. For AM, MZM and EAM the best performing pulse shape is Gaussian pulse shape in which the maximum Q factor is acceptable as per OFC standard.

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