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Optical millimeter wave generation using External Modulation – A Review.

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ABSTRACT

Background:- Millimeter wave (mmw) generation is a method used for high broadband data transmission with better data rate due to its high capacity bandwidth. **Objective**:- To understand the different external modulation schemes used for the generation of mmw and to prepare a comprehensive survey on the same. **Result**:- In this paper different types of modulation scheme for the generation of mmw is studied. By using the experimental setup using different modulation scheme for getting the frequencies like quadrupler, octupling and 12 tupling are discussed. In the intensity modulation, the mmw is generated by changing the modulation and bias voltage of the Mach Zehnder Modulator (MZM). Integration modulation is performed by a network of MZM and by changing the phase of signal the phase modulation is done. In the carrier suppression modulation method, the suppression of side band of signal is performed to generate the mmw signal. **Conclusion**:- This paper presents a survey on various types of external modulation methods employed in mm wave generation. The arrangements taken by the researchers for doing experiments using MZM for the generation of mm wave is also analyzed in the survey. This review gives an overall idea regarding the use of external modulation and its advantages such as the elimination of fading effect and chromatic dispersion. In every classification of external modulation the quality of signal transmitted through the optical fiber is verified by using the visualizers like optical spectrum, eye diagram and BER analyzers.

KEYWORDS: mm wave; External modulation; Intensity modulation; Phase modulation; Carrier Suppression modulation

INTRODUCTION

In the telecommunication field the optical communication is considered to be one of the best medium for high speed transmission in broadband systems. When compared to the electrical domain the data rate is high in the optical domain and the quality of the signal is better for long distance transmission. Nowadays for the transmission of data like videos and multimedia high bandwidth is required. In optical communication the bandwidth used is in the order of Megabits per second (Mbps) but the data transmission in this bandwidth has a major limitation that large amount of data transmission is difficult due to its low bandwidth range. In this situation mm wave frequency has got better efficiency due to its large bandwidth and data can be transmitted at the rate of Giga bit per second (Gbps)[1]. The rate of data transmission is in the order of Gbps in radio over fiber (RoF) communication reduces the fading effect and more capacity due to the high bandwidth has motivated the researchers to pursue experiments for the generation of mmw in the field of optical communication [2] - [8].The generation of mm wave can be possible by using external modulation and it is widely preferred due to the availability of large bandwidth. Generation of mm wave using external modulation can be classified based on intensity, integration, and phase and carrier suppression. Intensity modulation technique can be further subdivided based on interconnection, optical principle and by local oscillator. This method is used to map the optical signal into the mm wave range by using the external modulator such as an electro-optic modulator like

MZM. The scientist named O'Reilly et al. in the year 1992 has done experiment in MZM and proposed that using MZM is the better way for the generation of mm wave signal [9]. This modulator has the ability to increase the modulation of signal and the advantage of using MZM includes the transmission of signal for a long distance without using amplifiers and it has simple configuration.

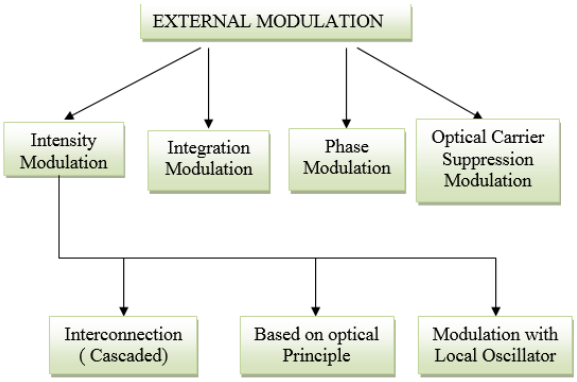

Fig. 1: Classification of modulation – A Flow chart

The figure 1 shows the classification of modulation schemes used in the field of mm wave generation for long distance transmission through an optical fiber. In all these modulation types MZM plays a vital role. An intensity modulation can be organized into different classes based on interconnection, optical principle and via local oscillator.

2. Working:

The main function of the MZM is to control the amplitude of an optical wave. The figure 2 shows the basic working principle of a MZM.

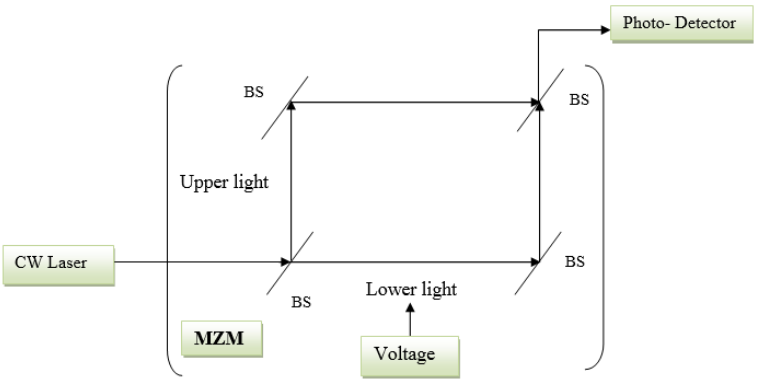

Fig. 2: Basic working model of a MZM

In figure 2 the laser is operated in continuous wave (CW) mode and the laser light falls on a beam splitter (BS), here the light signal is divided into two light signals which is indicated as upper and lower light signal. A voltage is applied across lower light area and thus a phase shift occurs while in the upper light there will be no phase change. Beam splitters are employed to recombine the light which is applied as an input to photo-detector. Due to the phase difference between the two light waves, the recombined light resembles an amplitude modulated signal which is further transmitted through an optical fiber.

3. A review on external modulation:

When laser is used to generate mm wave, the maximum frequency signal that can be generated is 40 GHz. However the wave generated using laser does not support long distance communication. Hence mm wave generation using the concept of external modulation like electro-optic modulator is a viable option. The following section presents an overview on the works performed by researchers in the field of mm wave generation using external modulation.

3.1 Intensity Modulation:

Intensity modulation is a method based on the laser source which directly modulates in mm wave range to an optical fiber. The highest frequency of a laser is about 40 GHz [10]. This mm range is not applicable for a

long distance transmission through an optical fiber because of its fading effect at the receiver side the quality of the data will get reduced. To overcome the drawbacks of direct intensity modulation MZM is used as external intensity modulation. This external modulation will increase the modulation of light which falls in the mm wave range. There are different schemes of external intensity modulation and the analysis performed by researchers under each scheme is detailed below.

3.1.1. Cascaded Intensity Modulator:

The MZMs are arranged in a cascaded manner for the generation of mm wave signal. Optical mm wave generation based on frequency quadrupler for a 40 GHz in RoF system is introduced by using a cascaded method [11] and for the generation mm wave based on frequency tripling up to 60 GHz [12]. In this both cases two $LiNbO_3$ MZM external modulators are arranged in a cascaded manner and carrier suppression scheme is used for the suppression of carrier signal. In the quadrupler scheme the significant advantage is the absence of optical and notch filters. In the frequency tripling method data rate at 2.1 Gbps is transmitted through a single mode fiber. In both the works tolerance to dispersion and low bandwidth requirement enables the experiments to produce quality signals.

3.1.2 Intensity modulator based on optical principle:

Even though various lasers are used as source to produce the light signal, the most widely preferred laser in external modulation is continuous-wave (CW) laser. The experiment was done by using gain switched laser as externally modulated and directly modulated for the comparison [13]. In the externally modulated scheme MZM is used for the generation of mm wave and transmitted for a distance of 3 km through a single mode fiber. The directly modulated signal was given to the photo-detector without using external modulator. Both the experiments are compared to infer that the external modulation technique is better than the direct modulated technique based on its high bit rate performance.

A distributed feedback laser which has high purity and high power with wide frequency tenability is used to produce a 60 GHz mm wave [14]. It is produced by using master/slave method and the system having MZM is considered as the master circuit which is used to generate mm wave. The mm wave generated by the master circuit is carried to the slave circuit to activate the carrier suppression mode and also given to photo-detector to convert the optical signal into electrical signal. An amplifier is used in the receiver side to reduce the fading effect and thus over 13 km the data has been sent over uplink and downlink.

3.1.3 Intensity modulator with local oscillator:

A system to produce optical mm wave and low bandwidth intensity modulator is used with low frequency local oscillator [15]. Single side band and double sideband suppression are employed to the external modulator MZM by adjusting the modulation voltage and bias voltage. The data is transmitted through a single mode fiber for a distance of 20 km. By using the single sideband suppression mode there is a better reduction of chromatic dispersion and requires less bandwidth for the transmission of data.

3.2 Integration Modulation:

The modulation of mm wave is performed by a single device and that single device will act as a MZM by using its integrated connection. The MZM used for the generation of mm wave is dual-electrode MZM and it has two electrodes which independently vary the chirp parameter for the transmission of data in the speed of 51.8 Mbps up to 80 km [16]. The optical carrier suppression scheme is used to suppress the carrier signal and a significant gain is achieved by this experiment in the long distance transmission of data through optical fiber without any distortion.

The frequency quadrupler is generated by using single integrated MZM which contain three MZM as an integrated connection for the generation of mm wave as shown in the figure 3.

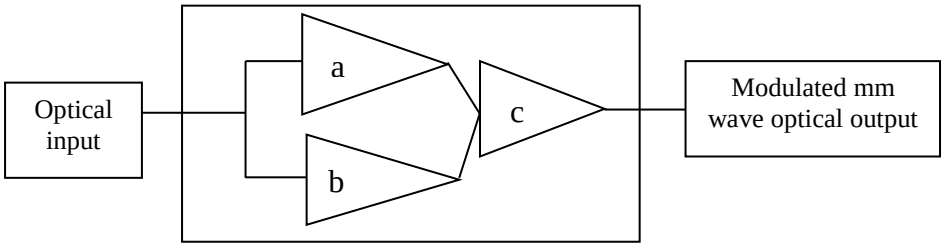

Fig. 3: Integrated connection of a MZM (a- MZ-a; b- MZ-b; c- MZ-c)

The modulation device has three MZMs named as MZ-a, MZ-b and MZ-c and the MZ a and b are connected to MZ-c [17]. The advantage of this scheme is no optical filter is used and due to the integrated connection of MZM the frequency can be increased up to 160 GHz.

3.3 Phase Modulation:

In this section the millimeter wave generated by the external modulation is modulated by changing the phase of the signal. The phase of the signal is changed by the MZM to perform optical carrier suppression and thus data rate up to 2.5 Gbps can be transmitted in mm wave range [18]. The dual arm MZM modulator is used in the experiment to change the phase of the light signal for a distance of 10 km through a single mode fiber such that data is transmitted with less distortion and caters to multiband services.

A method to generate a frequency doubling photonic 16-Quadrature Amplitude Modulation (16-QAM) is performed by using single phase modulator [19]. In this experiment the MZM is used for the phase modulation, the pseudo random bit sequence of 2 Gbps is applied to the 16-QAM modulation and the phase modulated signal output will given to the amplitude and phase pre-coding circuit. After pre-coding the data will be passed through a low pass filter and by selecting the required wavelength using a wavelength selective switch circuit for transmission over a distance of 22 km at a frequency of 40 GHz which fall in the mm wave range.

3.4 Optical Carrier Suppression Modulation:

The common technique used in all mm wave generation experiment to acquire the required frequency spectrum is by using carrier suppression modulation scheme. For the generation of mm wave the optical carrier suppression modulation plays a leading role and MZM is a device which supports the carrier suppression scheme for getting the frequencies in mm wave range [20]. The frequency quadrupler (four times the input frequency) is produced by using carrier suppression modulation scheme in $LiNbO_3$ MZM to transmit a data rate of 2.5 Gbps for a distance of 40 km through a single mode fiber.

The optical carrier suppression is performed by using external modulator and four wave mixing scheme is introduced [21]. Four wave mixing is a type of amplifier which is produced by using a circuit named as semiconductor optical amplifier (SOA). Interleaver can perform carrier suppression during the modulation process and thus 12-tupling frequency is produced to carry the pseudo random data to the receiver at a long distance through a single mode optical fiber.

4. Comparison of modulation schemes:

The table 1 shows the advantages and disadvantages of different modulation schemes used for the generation of mm wave.

Table 1: Comparison of different modulation methods

Modulation	Advantages	Disadvantages
Intensity	• Flexible • easily implemented • Efficient • Tolerance to dispersion	• For a long distance transmission fading effect will be more. • Amplifiers are used to reduce fading effect.
Integration	• Quality of the signal is better • Fading effect is less	• Complex • high cost
Phase	• Modulation can be done by changing the phase of the signal. • Simple configuration	• High power consumption. • More amplifiers are used.
Carrier Suppression	• Can be implemented with all modulation schemes. • Less cost	• High dispersion effect • Need a support from a modulator to function.

Conclusion:

The mm wave generation using external modulation is an emerging technique for the transmission of data through an optical fiber in the field of optical communication. This paper presents a survey regarding various types of external modulation methods employed in mm wave generation. The experimental setup suggested by the researchers for doing experiments using MZM for the generation of mm wave is comprehensively discussed in the survey. This review gives an overall idea regarding the use of external modulation and its advantages such as the elimination of fading effect and chromatic dispersion. The intensity modulation scheme is used in many experiments due to its less complexity, high efficiency and less cost. In every classification of external modulation the quality of signal transmitted through the optical fiber are analyzed by using the visualizers like optical spectrum, eye diagram and BER analyzer.

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