UWB doublet generation using nonlinearly-biased electro-optic intensity modulator

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A novel and simple method to generate an ultra-wideband (UWB) doublet using an electro-optic intensity modulator (EOM) is proposed and experimentally demonstrated. The EOM is biased at a nonlinear region near the maximum or minimum point of its transfer function. When a Gaussian pulse is applied to the EOM, the pedestal or the peak part of the pulse is inverted, leading to the generation of a UWB doublet.

Introduction: Ultra-wideband (UWB) impulse radio is a promising technology for short-range high-capacity wireless communication systems and broadband sensor networks, owing to its high data rate, low power consumption, very low power spectral density, and immunity to multipath fading [1, 2]. The US Federal Communications Commission (FCC) has defined that a UWB device is one that has a bandwidth equal to or greater than 20% of the centre frequency or that has a bandwidth equal to or greater than 500 MHz. The FCC has also permitted the unlicensed use of the UWB band from 3.1 to 10.6 GHz with a power density lower than −41.3 dBm/MHz (FCC: part 15) [2].

Most of the approaches to generating UWB signals proposed previously were based on pure electronic methods [3, 4]. Recently, the generation and distribution of UWB signals in the optical domain, by taking the advantageous features of low loss and light weight of state-of-the-art optical fibres, has attracted a lot of interest [5]. Several approaches have been proposed [6, 7]. In [6], a specially-designed modulator that consists of four optical phase modulators with three electrodes is used to generate a UWB doublet pulse. In [7], a UWB doublet is generated and distributed by using an optical phase modulator in combination with a length of singlemode fibre (SMF). Thanks to the chromatic dispersion of the SMF, the phase-modulated (PM) signal is converted to an intensity-modulated (IM) signal with a transfer function equivalent to a bandpass filter, which is used to shape the spectrum of a Gaussian pulse to that of a UWB doublet. The two approaches in [6] and [7] can optically generate a UWB pulse, but they need to use either a specially-designed optical modulator or an optical phase modulator with a long SMF.

In this Letter, we propose and demonstrate a novel and very simple method to generate a UWB doublet pulse that uses only a single electro-optic intensity modulator (EOM). The fundamental principle is to shape the Gaussian pulse by inverting the pedestal or the peak part of the Gaussian pulse, which is realised by setting the bias voltage of the EOM to near the maximum or the minimum transmission point of its transfer function. The proposed approach is experimentally demonstrated. When a Gaussian pulse with a pulse width of 270 ps is applied to the EOM, by appropriately adjusting the bias voltage, a UWB doublet that has a pulsewidth of 270 ps and a −10 dB spectrum bandwidth of 8 GHz centred at 4 GHz is obtained.

Principle: The principle of the proposed UWB doublet generation is shown in Fig. 1. Usually, an EOM has a transfer function given by

$$P_{out} = \frac{1}{2} P_{in} \left\{ 1 + \cos\left[\frac{\pi}{V_\pi} V_{bias} + \frac{\pi}{V_\pi} V(t) \right] \right\} \quad (1)$$

where P_{in} and P_{out} denote the input and output optical power, $V(t)$ is the voltage of the electrical modulation signal, V_{bias} is the bias voltage, and V_π is the half-wave voltage of the EOM.

An electrical Gaussian pulse is applied to the EOM that is biased near the maximum or minimum transmission point (point A or B in Fig. 1). Owing to the nonlinear nature of the transfer function, the shape of the Gaussian pulse will be changed. If the amplitude of the modulation Gaussian pulse is large enough, the pedestal part and the peak part of the modulation pulse would lie in the positive and negative slopes or the negative and positive slopes, respectively, depending on the bias point on the transfer function curve. Therefore, the pedestal or the peak part of the Gaussian pulse is inverted, and a UWB doublet is thus obtained, as shown in Figs. 1*a* and *b*. In addition, by switching the bias points between A and B, the polarity of the UWB doublet is reversed. This property is interesting, since it provides a simple method to implement pulse polarity modulation (PPM).

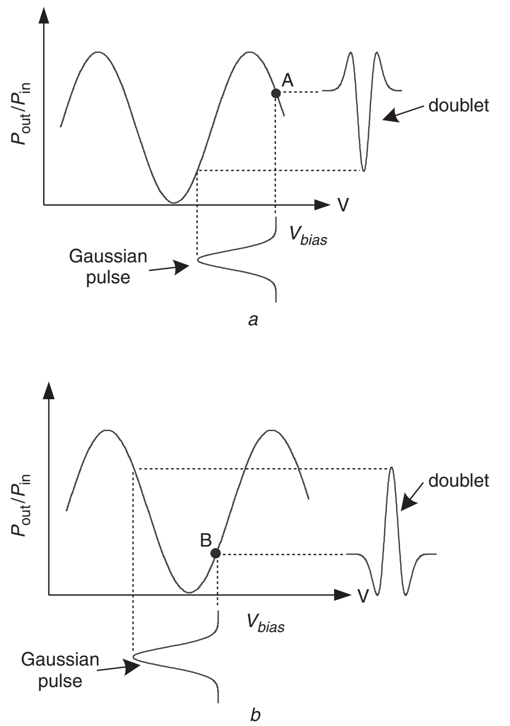

Fig. 1 *Principle of UWB doublet generation by using nonlinearly biased EOM*

a When biased near maximum transmission point
b When biased near minimum transmission point

Experiment: An experiment was carried out to demonstrate the proposed approach. The experimental setup is shown in Fig. 2. In the setup, the output of a laser diode (LD) is fed to a commercial EOM (JDS, OC-192 modulator, 10024180) that is modulated by a Gaussian pulse train generated by a bit error tester (BERT, Agilent N4901B). Then, the output of the EOM is amplified by an erbium-doped fibre amplifier (EDFA) to compensate for the insertion loss of the EOM. A tunable optical bandpass filter (TBPF) is connected after the EDFA to remove the amplified spontaneous noise (ASE) of the EDFA. The output from the TBPF is sent to a high-speed photodetector (PD). The generated electrical UWB doublet would be obtained at the output of the PD. In the experiment, the electrical Gaussian pulse from the BERT has a pulse width of 270 ps, a repetition rate of 8.0 Gbit/s with a fixed pattern '1000 0000 0000 0000', which is equivalent to a Gaussian pulse train with a repetition rate of 0.5 Gbit/s and a pulsewidth of 270 ps. Here, the pulsewidth is defined as the width between the two points having a level of 5% of the pulse magnitude. Two broadband electrical amplifiers, AMP1 and AMP2, are used to amplify the Gaussian pulse train and the electrical UWB signal at the output of the PD, respectively.

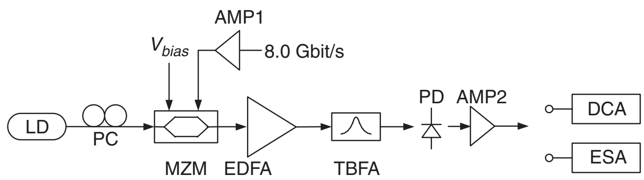

Fig. 2 *Experimental setup for UWB doublet generation*

In the experiment, we adjust the bias voltage and monitor the waveform and RF spectrum of the generated doublet pulse by using a digital communication analyser (DCA) and an electrical spectrum analyser (ESA). When the bias voltage V_{bias} is adjusted to be −0.7 V, the pedestal part of the Gaussian pulse lies in the negative slope in the transfer function while the peak part lies in the positive slope. Therefore, the pedestal part is inverted, leading to the generation of a UWB doublet, as shown in Fig. 3*a*. The corresponding spectrum is shown in Fig. 3*b*. The UWB doublet has a width of about 270 ps. The ripples at the right side of the doublet are mainly caused by two electrical amplifiers. The spectrum has a centre frequency at about 4 GHz and a −10 dB bandwidth of about 8 GHz. Since the input Gaussian pulse train is periodic, the output spectrum is discrete. The spacing between two neighbouring spectrum lines is measured to be 0.5 GHz, which is equal to the repetition rate of the doublet pulse. The polarity of the UWB doublet pulse can be changed by switching the bias points. In the experiment, when V_{bias} is switched from −0.7 V to −7.0 V, a UWB doublet with a reversed polarity is obtained, as shown in Fig. 3*c* with its spectrum shown in Fig. 3*d*. Note that the amplitude of the UWB doublet in Fig. 3*a* is much lower than that in Fig. 3*c*. This is caused by the saturation of the PD when the bias point is near the maximum point. As can be seen from Fig. 1 the average optical power in Fig. 1*a* is much higher than that in Fig. 1*b*, which causes the saturation of the PD, leading to a lower photodetection gain.

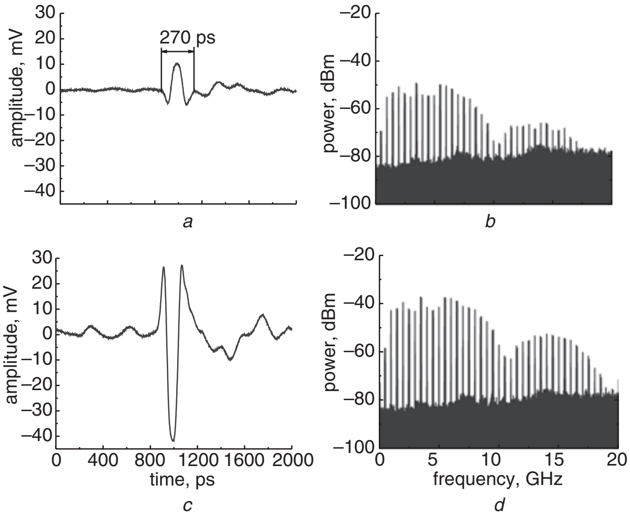

Fig. 3 *UWB doublet generated from nonlinearly biased EOM*

a $V_{bias} = -0.7$ V, waveform
b $V_{bias} = -0.7$ V, spectrum
c $V_{bias} = -7.0$ V, waveform
d $V_{bias} = -7.0$ V, spectrum

Conclusions: A novel and very simple method to generate a UWB doublet pulse based on an EOM that is nonlinearly biased has been proposed and experimentally demonstrated. The key function of the EOM is to shape the input Gaussian pulse by inverting the pedestal or the peak part of the Gaussian pulse, which was realised by setting the bias voltage of the EOM to near the maximum or the minimum point of the transfer function. In the experiment, a UWB doublet pulse with a width of about 270 ps and a −10 dB spectrum bandwidth of 8 GHz centred at 4 GHz was generated. By switching the bias points, the polarity of the doublet can be reversed, which could be used to implement pulse polarity modulation in a UWB system.

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