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PHASE SHIFT KEYING OPTICAL COMMUNICATION BY MACH ZEHNDER TECHNIQUE USING SINGLE LASER

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RINGKASAN : *Sistem komunikasi optik penguncian anjakan fasa dua saluran menggunakan sebuah punca cahaya laser disiasat. Interferometer Mach-Zehnder digunakan untuk mengkod isyarat dan teknik homodin digunakan untuk menyahkod isyarat di dalam eksperimen ini. Dalam sistem ini, sumber cahaya dipisahkan kepada tiga bahagian yang masing-masing mempunyai satah pengutuban yang tersendiri, dua bahagian digunakan untuk membawa isyarat dan bahagian ketiga digunakan sebagai rujukan. Ketiga-tiga isyarat digabungkan sebelum penghantaran dilaksanakan pada penghantar dan dinyahkod secara berasingan pada penerima dengan bantuan gelombang rujukan.*

ABSTRACT : Two channels Phase Shift Keying optical communication system using a single laser light source was investigated. In this experiment, Mach Zehnder Interferometer was used for encoding signals and homodyne technique for decoding signals. In this system, the light source was split into three parts each having its own plane of polarisation such that two parts were used for carrying signals and the third part was used as a reference. All three optical signals were combined before transmitting on the transmission side and decoded independently on the receiving side with the help of the reference wave.

KEYWORDS : Homodyne technique, optical communication, Phase Shift Keying (PSK), encoder and decoder

INTRODUCTION

During the past decade, communication using optical wave has increased exponentially. This is due to many factors like availability of reliable and cheaper Erbium Doped Fibre Amplifier (EDFA) which means that the optical signal can be amplified easily without loss of information. Similarly tune-able Erbium Doped Fibre Laser (EDFL) and Dense Wavelength Division Multiplexer (DWDM) have been developed. Even with such development, demand for longer distances with higher data transfer rate is ever increasing. For longer distances, high gain EDFA with different technique is developed (Bouzid *et al.,* 2003). Data transfer rate can be improved by two different techniques. One way is by increasing the number of channels in single fibre laser source. Fifteen channels fibre has been reported (Saharudin *et al.*, 2004). Twenty two channels fibre laser with low threshold fibre laser is also reported (Bouzid *et al.,* 2004). Though the number of channels is on the increase, initial tuning of different channels over a wide range is still a problem. However, at present, tuning fibre laser from 1525 nm to 1565 nm is possible. Another way for improving the data rate transfer is to improve detection techniques. Highly sensitive modulation / differential detection technique is developed (Abdullah *et al.,* 2003).

All techniques described are expensive and difficult to use. We have developed a new passive technique to increase the number of channels by dividing each channel into two orthogonal polarised light waves.

In this article, it is shown that the number of channels can be doubled by using different plane polarised light signals that can be decoded using homodyne technique. The advantage of this detection technique is that it is very efficient. On the other hand, when heterodyne technique is used, 30.6% power of the signal goes to the first order sideband and about 69.4% of the power is wasted. In heterodyne technique, two channels cannot be placed too close to each other because in doing so, interference between the second and the third order side band may occur. In this experiment, homodyne technique is used, in which it is both improving the SNR and highly efficient.

It is an established fact that homodyne detection of PSK signals offers the best sensitivity of any binary signaling techniques, as well as high channel packing density, reduced receiver's thermal noise and required minimum receiver's bandwidth (Khan *et al.,* 1989). For this purpose balanced phase-locked loop is usually used (Sun & Ye *et al.,* 1990).

In optical communication, the information in the form of optical wave is coded first and then transmitted. On the receiving end of the system, the information carrying the signal is mixed with local oscillator which helps in detection and decoding of the information. However, the need for providing a local oscillator at the receiving end can be eliminated by transmitting the signal light-wave along with the reference light-wave. By the interaction of reference light-wave with the signal carrying-wave, the information can be decoded at the receiving end. This article reports the use of this technique but this can only be accomplished in free space or polarisation in maintaining the optical fibre.

The design and experimental setup for two channel communication system using polarisation concept is given as follows.

MATERIALS AND METHOD

This experimental set-up is for a communication which carries a dual channel, dual-polarisation, phase modulated light signal from a single laser light source. Figure 1 shows the experimental setup.

Polarised light from a laser diode (LD) with 630 nm wavelength, 3 mW output power, and 1×10^9 Hz full width at half maximum – FWHM, which is equivalent to about 30 cm coherent length was split into two beams by using Non-Polarised Beam Splitter (NPBS). One beam was reflected towards the mirror M1 and was treated as a reference beam and the other beam was further split into two equal orthogonal light-waves by the Polarised Beam Splitter (PBS1). These two orthogonal light-waves were encoded by piezo-electric devices that were coupled to the mirrors M3 and M4 independently. The coding here is done by the movement of the mirror by Piezo-electric device. Piezo-electric is an electro-mechanical device that could not code signals at a very high frequency but is fast enough to demonstrate the phase modulation. In real PSK system, this can be replaced by Lithium Niobate ($LiNb_3$) crystal which can generate phase modulation at several hundreds mega Hertz. If Lithium Niobate crystals are used, the first one should be placed between the mirror (M3) and Polarised Beam Splitter (PBS2) and the second between the mirror (M4) and the Polarised Beam Splitter (PBS2).

These two signal-encoded light-waves were combined by PBS2 after reflecting from mirrors M3 and M4, respectively. Further, these waves were combined with the reference light-wave by glass plate (GP), before the reference light wave was reflected by mirror M2 that was set at 45° as shown in Figure 1.

These three light-waves travelled in free space or in polarisation in the optic fibre. At the receiving end, two polarised light-waves were separated by Polarised Beam Splitter (PBS3). Reference light-wave was also split into two parts. This Polarised Beam Splitter (PBS3) also separated two signals carrying polarised light waves. Each polarised signal light-wave will interact with the reference light-wave. Two separate detectors will detect the decoded signals. In this way, the two channel phase which modulated the communication from a single laser light source was achieved. Two Half-Wave Plates HWP1 and HWP2 were introduced between PBS1 and M3, PBS1 and M4 respectively just to change the plane of polarisation.

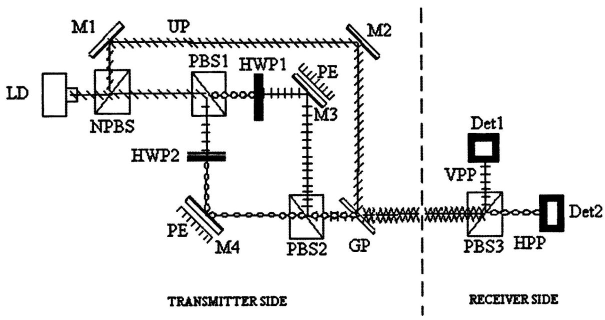

Figure 1. *A single source of two channel PSK optical communication system*

Legend

LD	Laser Diode	PBS1, 2.3	Polarised Beam Splitters
Det1, 2	Detectors	NPBS	Non-Polarised Beam Splitter
GP	Glass Plate	PE	Piezo-Electric
M1, 2, 3, 4	Mirrors	HPP	Horizontal Plane Polarised Light
UP	Unpolarised light	VPP	Vertical Plane Polarised Light
HWP1, 2	Half-Wave Plates		

RESULTS AND DISCUSSION

To test the optical design, a circuit using simple TTL devices were constructed which generated two different types of electrical signals. The circuit diagram for these signals is given in Figure 2.

These were used as input signals for channel-A and channel-B. Actual signals are shown in Figure 3.

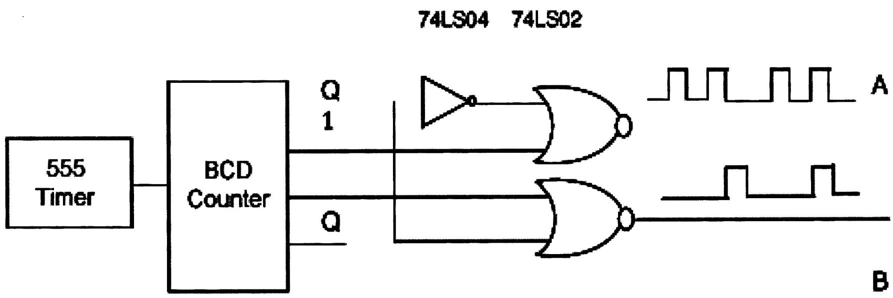

Figure 2. *TTL logic to generate two different signals with fixed phase difference*

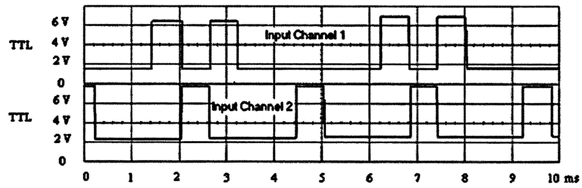

Figure 3. *Two input signals generated by TTL circuit with constant phase difference*

Signal-A and signal-B were used as input signal for channel-1 and channel-2 respectively. Firstly, channel-1 was activated while channel-2 was off. The output of channel-1 was recorded on the receiver side by a photo detector. Input and output of channel-1 are plotted simultaneously as shown in Figure 4. Secondly, channel-2 was activated while channel-1 remained off as shown in Figure 5. There are two types of input and two types of output. First two inputs were generated by TTL, which are like square waves. Once these two inputs are connected to the piezo-electric, optical signals, which are not exactly square waves, are generated. This is due to the inertia of the piezo-electric and the inertia of the mirror. When TTL input is connected with the piezo-electric, the signal is distorted so that the optical output is also distorted as shown in Figure 6. The mirrors M3 and M4 act as inputs as they are connected with channel A and channel B.

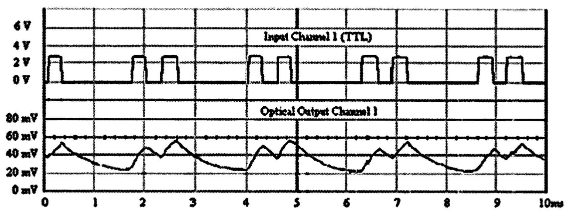

Figure 4. *Channel-1 after it is connected to piezo-electric device and its optical output*

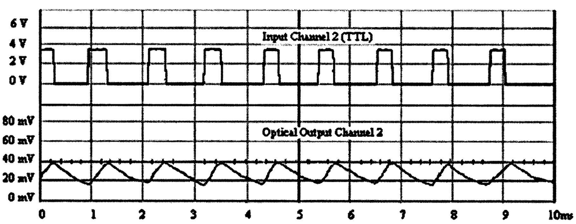

Figure 5. *Input channel-2 at TTL output and corresponding output at receiver end*

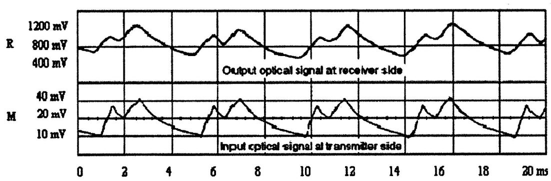

Figure 6. *Optical input and optical output for channel 1*

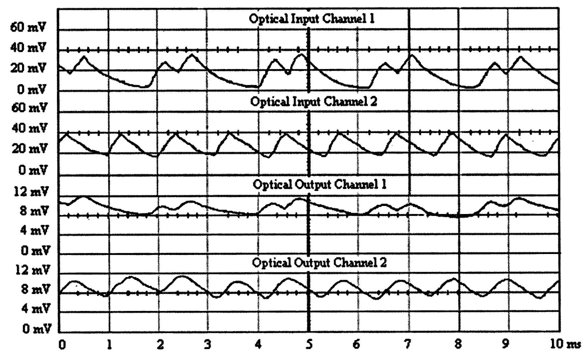

Figure 7. *All four channels, two input and two output channels plotted simultaneously*

Lastly both inputs were given to channel-1 and channel-2 simultaneously. Their inputs and outputs were recorded and plotted simultaneously as shown in Figure 7.

CONCLUSION

Two channel Phase Shift Keying were produced as shown above by using the Mach Zehnder Interferometer to encode the signal and the homodyne technique to decode it. Hence, results show that the output signal resembles the input signal. The other observation is that both the channels are independent of each other. Close observation reveals that there are two kinds of distortions. First, is in the shape of the wave. Input signal is square wave and the output signal looks like a sine wave. It is due to the high capacitance of piezo-electric device. When the input signals are recorded before the piezo-electric drivers, they are of square wave shape. If we record signals after piezo-electric driver, then the output signals are the exact replica of input signals. Secondly, there is a time delay between input and output signal. This time delay is less than 10^{-3} second. This time delay is due to inertia of the mirror attached with piezo-electric.

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