CHAPTER 4

4.0 PSK Communication

4.1 Introduction

Coherent communication systems can be considered to have began since early 1980 when some experiments demonstrated the feasibility of the fiber optics transmission. The advantages of the optical communication stem from wider bandwidth and longer repeater spans. Moreover, the possibility of using Wavelength-Division-Multiplexing (WDM) of a large number of optical channels with very narrow frequency separation has given a further push to the development of more efficient coherent communication.

However some, problems have been encountered in developing coherent optical system. The theoretical quantum limit for optical coherent communication system is around nine photons per bit that seems to be attainable by mean of homodyne Phase-Shift-Keying (PSK). As a matter of fact the feasibility of such system is strongly dependent on the ability of a few light sources and the increase of channels using the same sources.

As regards to the first problem it is notable that PSK system with amplitude division by using polarized and non-polarized beam splitter provides the best solution. Intensity of the light from the single source can be divided and can be reused instead of introducing different light sources. Though during splitting and recombining the light waves do create loss of power but overall the system remains in homodyne, that means all information remain in the base band whilst still using the coherent property.

Similarly for bulk optics including wave-plates, and beam-splitters the number of channels can be increased. This type of work has been conducted earlier but the full extent of this technique has not been exploited fully.

Modulation schemes for coherent communication systems include amplitude shift keying (ASK), phase shift keying (PSK), frequency shift keying, and differential phase shift keying.

The method of demodulation is important factor in determining the selection of modulation scheme. There are two types of modulation, which are distinguished by the need to provide knowledge of the carrier phase. Demodulation scheme requiring the carriers phase to be known are called coherent. Those that do not need the carrier phase to be known are termed incoherent. Incoherent demodulation can be applied to ASK and wide-band FSK. It describes demodulation schemes that are sensitive only to the power of the signal. Whereby ASK, the power is either present or it is not present and with wide-band FSK, the power is either present at one frequency or the other but both replacing digital signals. Incoherent modulation is inexpensive but has poor performance. Coherent demodulation requires more complex circuitry, but it has better performance. For coherent demodulation systems, the incoming signal is compared with a replica of the carrier wave. This is obviously necessary with PSK signals, because in the signal is constant in amplitude and frequency. Complete mathematical expressions were given in the previous chapter.

Homodyne PSK offers the highest sensitivity of any coherent detection system. Another big advantage of coherent optical communications system is that they allow a narrow channel spacing for wavelength division multiplexing (WDM). Multiplexing refers to any of several techniques used to pack more information on a single fibre by simultaneously transmitting several signals over the same fibre. To avoid senseless gibberish at the receiving end, each signal can be uniquely tagged in a way that the receiver can recognise individual wavelengths. WDM accomplishes this by delivering each signal on a slightly different laser frequency that is then optically filtered before the receiver. Besides WDM, another important kind of multiplexing is Time-Division Multiplexing (TDM). TDM segregates samples of each signal into separate time slots that the receiver can clock off individually. With WDM, each signal is carried on a separated sub-carrier frequency that can be electrically filtered out by the receiver.

A PSK system can be divided into many groups depending upon mode of signal encoding, communication media, method used for decoding.

4.2 Mode Of Encoding

In binary phase shift keying (BPSK) the change in phase is either 0 degrees or 180 degree. In the case of quarter-phase shift keying (QPSK) the change in phase shift is 90 degree while in case of M-ray or multiple phase shift keying (MPSK) the phase angle change is less than 90^0.

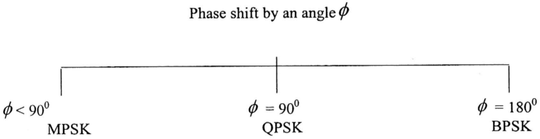

Fig. 4.1 The different PSK phase shifting schemes, ranging from $\phi < 90^0$ to 180^0

4.3 Mode Of Detection

For detection the signal carrying lightwave has to interact with another lightwave before the light detector can detect it. On the basis of detection, it can be easily divided into two main categories heterodyne and homodyne. In homodyne the reference light wave has same wavelength as the signal carrying light wave while in heterodyne the reference light can have a different wavelength.

Again heterodyning can be subdivided into more groups depending upon encoding and decoding methods. Detailed explanation of DPSK is given on page 60.

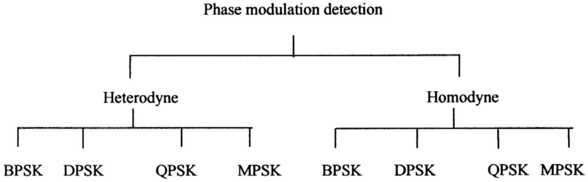

Fig. 4.2 Subgroup division of phase modulation detection

4.4 Mode Of Communication

It has been demonstrated by many researchers that PSK communication is possible with all kind of electromagnetic waves. In fact now PSK modems are available especially in the radio wave frequency. Many satellites communicate though PSK system.

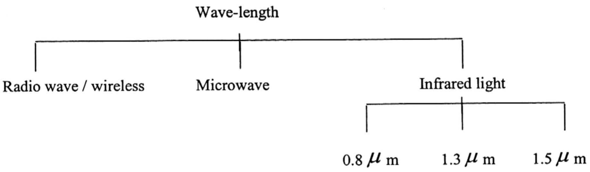

Fig. 4.3 The electromagnetic spectrum range to which PSK can be applied to.

4.5 Medium

PSK communication is possible in space, like satellite to satellite, e.g. in atmosphere such as in mobile telephone, and in also in polarisation maintaining optical fibre. Usually for different mediums different wavelengths of the electromagnetic waves are used.

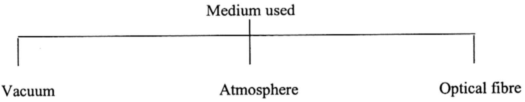

Fig. 4.4 The range of medium over which appropriately designed PSK system, can work.

Combination of all these modes can provide lot of different type of PSK communication systems.

4.6 Phase Shift Keying (PSK)

The phase shift keyed system transmits a carrier of one phase for the binary 1 and a different phase for the binary 0. The amplitude and the frequency will remain constant for both. Binary phase shift keying (BPSK) there are only two phases for representing a 0 and 1. The signal is encoded by changing its phase by 180^0.

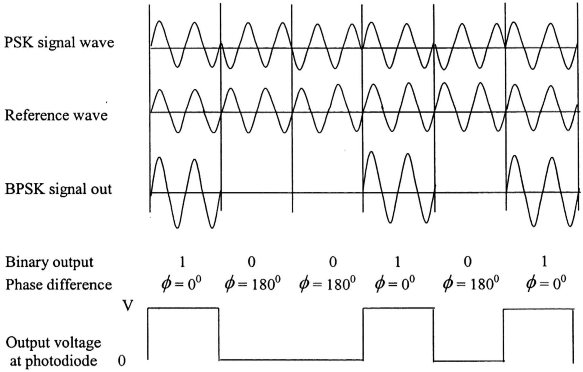

Fig. 4.5 Symbolic representation of the detection of a PSK

Since phase shift keying offers simple way of increasing the number of levels in the transmission without increasing the bandwidth by introducing smaller phase shift, it is also possible to have a phase shift $\phi = 90^0$ which is called Quadrature phase shift keying which (QPSK) has four phases. M-ray has M phases and is denoted by MPSK. For a given bit rate, QPSK requires half the bandwidth of PSK and is widely used for this reason. The number of times the signal parameter (amplitude, frequency, and phase) is changed is called the signalling rate. It is measured in baud where 1 baud =1 change per second. In the case of binary modulations such as ASK, FSK, and BPSK, the signalling rate equals the bit-rate where with QPSK and MPSK, the bit-rate may exceed the baud rate. A scheme of using QPSK provides a very acceptable performance level with a near minimum RF bandwidth.

The processing of QPSK is more complicated than PSK because two separate demodulators are required. The demodulator complexity increases rapidly for M-ray PSK and for this reason it is rarely used.

The difficulty with coherent detection is the need to keep replica signal, termed local oscillator 'locked" to the carrier and this is not easy to do. Oscillators are sensitive to temperature, and a free running oscillator will gradually drift in frequency and phase.

There are two methods to prevent such an occurrence in one, a pilot carrier signal is sent together with the modulated carrier. This pilot carrier is used to synchronise the local oscillator phase. The alternative is to employ another form of modulation, differential phase-shift-keying (DPSK). DPSK is actually a simple form of coding where The modulating signal is not the binary code itself, but a code that records changes in binary code. This way, the demodulator only needs to determine changes in the incoming signal phase and because the drift associated with the local oscillator occurs slowly, this is not difficult to arrange.

A PSK signal is converted to DPSK by following two important rules which are

1. a "1" in the PSK signal is denoted by a no change in the DPSK
2. a "0" in the PSK signal is denoted by a change in the DPSK signal

PSK		0	1	0	0	1	1	0	1
DPSK	1	0	0	1	0	0	0	1	1

However some problems have been encountered in developing coherent optical systems so that the theoretical quantum limit for PCM systems, 10 photons per bit, which seemed to be attainable only by the means of homodyne PSK system. It is actually enough for large scale production and cost effective systems. Reliability of such systems is strongly conditioned by laser phase noise and fluctuation of state of polarisation (SOP) of the optical field at the output of conventional single mode fibres. As regards the first problem it is to be noted that a PSK system with synchronous detection, offering the best ideal performance requires optical source of very narrow spectral width. Even if a DFB laser or an external cavity laser is used in DPSK systems their reliability is still a critical parameter in practical application.

Lot of research has been done during the last ten years where researchers have tried to develop different methods of encoding signals, compensate dispersion, miniature packaging for PSK, etc. Some of their work and achievements are summarised below.

4.7 Encoding And Decoding For Narrow Band PSK Transmission Via Optical Fibre

In BPSK communication system one phase represent "0" and the other phase represents "1" and the phase angle difference between the two bits is 180^0. This phase angle can be reduced and in the case of QPSK this angle is 90^0 which also means that two independent signals can be transmitted over the same channel. Encoding and decoding for QPSK is a bit more difficult. As the phase angle decreases ($\theta < 90^0$) more and more signal can be transmitted but encoding and decoding becomes increasingly difficult too and after $\theta < 90^0$ BER increases rapidly.

A new technique was developed by H. Ikeda, K. Wakai, H. Fujita and H. Yoshida [13] to make narrow phase angle PSK transmission possible. They described a part of the coding and decoding circuits for use in the narrow-angle PSK system. Data of the normal QPSK system is in the sender fed to a divide-by-four frequency counter to make the shift angle narrow. The receiver feeds this data to a pair of frequency doublers to make the shift angle wider so that the normal QPSK data is obtained. Narrow-angle PSK data is transmitted from the sender to the receiver through optical fibres and by the use of the frequency counter and doubler the synchronising in the receiver is drastically improved and stabilised. This new concept of the optical narrow-angle PSK data transmission system has been experimentally verified to be effective and successful. The configuration of the total system is simple and it can effectively transmit data on multiple channels. Furthermore, this system can also be designed to be capable of bi-directional transmission of the optical signal by using an optical WDM and demodulator. JZ. Li, H. Ikeda [14] and K. Wakai [15] also confirm this.

4.8 Heterodyne Transmission DPSK System Experiment At 1.4 Gbit/S

J.M.P. Delavaux, L.D. Tzeng, M.Dixon and R.E.Tench [4] have systematically studied the variation of receiver as a function of low optical power in a 1.4 Gb/s DPSK transmission system experiment using balanced receivers. They have shown that the measured detection penalty versus low power has the same functional dependence as the theoretical prediction for shot noise limit detection, but it is shifted by an 8.5 dB offset. These results are similar to previous data reported at 400Mbit/s by J.M.P. Delavaux [5] with the difference that sensitivity penalty increases with bit rate from 2.6 dB at 400 Mbit/s to 8.5 dB at 1400 Mbit/s. This observation is consistent with early prediction by R.A. Valenzuela [6] and confirms ISI penalty, while increasing with bit rate remains independent of shot noise level. Based on their system evaluation, they define that the main contribution to ISI penalty results from the restricted transmitter bandwidth (i.e. modulator and associated electronics). Nevertheless their best receiver sensitivity of –42.8dBm with only 0.5mW(-3dBm) effective low power is the best result obtained at this bit rate using such a low optical power.

4.9 Fibre Distribution For 80 Compressed Digital Video Channel Using Differential QPSK

G.R Joyce, R. Olshansky and R.Gross [7] have conducted experiments of the carrier-to-non-linear distortion (CNLD) on Fabry Perot (FP) laser. Using FP laser the equivalent of

80 compressed MPEG digital video channels are transmitted through 18km of single mode fibre. The signals are transmitted on 20 sub-carriers with 6 MHz channel spacing using differential quadrature phase shift keyed (DQPSK) modulation and a simple delay time modulator. Their system has demonstrated the suitability of digital sub-carrier multiplexer optical transmission system for the distribution of compressed digital video in a subscriber loop. It uses a 6 MHz channel spacing in the 350 MHz – 470 MHz range, which is compatible with commercial TV equipment while employing both a low cost Fabry-Perot laser transmitter and a simple delay-line demodulator.

Quadrature amplitude modulation (QAM) consists of independently modulating the amplitude of two carriers both at frequency ω_C and $\pi/4$ out of phase.

4.10 1550-Nm Transmission Of Digitally Modulated 28-Ghz Sub-Carriers Over 77km Of Non-Dispersion Shifted Fiber

In 1994 H. Schuck and R. Hofstotter [1] demonstrated the transmission of a single mm-wave channel over long spans of fibre at 1550nm using heterodyne techniques. In their experiment they achieved distributive communication of 60GHz signals to more than 100 base stations. At about the same time D.Wake, C.R. Lima and P.A. Davies [2] achieved transmission of 60GHz signals over 100 Km of optical fibre, using a dual-mode semiconductor laser source. They also used a heterodyne technique for decoding optical signals. Later on John Park, A.F. Elrefarie and K.Y. Lau [3] have shown that even at fiber distance up to 76.7 km the inter-modulation distortion is low enough for acceptable transmission of multiple digitally modulated mm-wave carrier. For a QPSK modulated carrier in a non-dispersion minimum single mode fibre (NDSF) without optical amplification and in the presence of inter-modulation distortion from four adjacent channels a bit error rate below 10^{-9} was still achieved.

The significance of these results on the mm-wave fibre wireless system architecture is that a 28 GHz optical fibre link can be used to distribute broad-band QPSK information at mm-wave from a headend location to remote antenna sites up to at least 76.7 km away for broadcast services.

4.11 10-Gbps X 4-Ch. WDM Transmission Experiment Over 2400 Km Dispersion Shifted Fibre Using DPSK Direction Detection Scheme

Wavelength division multiplexing (WDM) technology can achieve very-large-capacity transmission however, four-wave mixing (FWM) is a serious limiting factor in the WDM transmission system using dispersion-shifted fibre (DSF). It has been shown that FWM-induced penalty can be reduced by unequal channel spacing and optical differential phase shift keying (DPSK) signalling. K. Yonenaga and K. Hagimoto [8] have demonstrated long haul transmission of four-channel multiplexed 10-Gbit/s optical DPSK signals using DSF. They used 2400 km DSF and using DPSK-DD system, high quality Q-factors were achieved as compared with that obtained using intensity modulation.

4.12 4-Gb/S Heterodyne Transmission Experiments Using DPSK And Other Modulation.

J.M. Kahn, A.H.Gnauck [9] have shows that PSK homodyne communication is also possible using a Nd:YAG laser with an external cavity. External cavities are used to create very narrow line width output but it is impractical for long distance communication because of the relatively high loss in normal single mode fibre at this wavelength. Later on A.H.Gnauch, K.C. Reichman [10] reported of an experiment of 4Gb/s asynchronous heterodyne light wave system in which PSK and DPSK modulation formats were investigated and transmission over 160 km of conventional fibre was achieved. Semiconductor lasers having sufficient narrow line width to allow DPSK operation at 4Gb/s were used. The sources were externally modulated using $LiNbO_3$ wave guide modulators. They studied the DPSK transmission over 175 km of dispersion shifted fibre at 1.528 μm and DPSK transmission over 160 km of conventional single-mode fibre (dispersion zero at 1.3μm wavelength) was also achieved. The predicted penalty for DPSK transmission is 0.0 dB. But in their experiment this penalty is 1.8 dB. They believe that this penalty in DPSK transmission system is due to inter-symbol interference, which made the system less tolerant of dispersion effects. The baseline receiver sensitivity for DPSK was 209 photons per bit transmission over 160 km of a conventional single-mode-fibre and it was achieved in the experiment.

4.13 Novel Technique For High-Capacity 60 Ghz Fibre-Radio Transmission Systems

L.Novel, D.Wake and D.G.Moedies [11] have used a new technique to combine QPSK data at 120 Mb/s and 20 channels of satellite TV, together with a 60 GHz carrier signal. They have also demonstrated high quality transmission in a fibre radio experiments at 60GHz using a number of new techniques. The have shows that a simple master-slave (M/S) distributed feedback (DFB) laser arrangement is capable of generating high-power and high purity carrier signals over a wide frequency range with excellent stability.

60 GHz signals with single-side band phase noise of only –100dB/Hz at 100kHz offset were generated using this technique.

A transparent data path was provided using a remote up-conversion scheme, which was used to avoid potential problems due to chromatic dispersion in the fibre and also modulation limitation imposed by the carrier source. An electro-absorption modulator (EAM) was used as the photodiode for the data path, and also as a modulator to provide a return path for the data, thereby removing the need for a laser at the remote site[36]. This device was shown to be capable of full duplex operation as a transceiver. These techniques were combined in a fibre-radio experiment with a fibre span of 13 km and a radio path of 5 m. The signal consisted of a 120 Mb/s QPSK data and 20 channels of TV for the downstream path. Good error performance was simultaneously achieved in both directions for a down stream path that included a radio drop and for a fibre-only up-stream path.

They have reported the first high-capacity 60GHz fibre- radio system, which incorporates an attractive strategy for the return path. Their techniques are promising in term of cost and practicality for wide spread deployment in future broad-band wireless system.

4.14 Atmospheric Optical Communication System Using Sub-Carrier PSK Modulation

PSK communication can be used in the free space outside the atmosphere. In the atmosphere PSK is only possible for few kilometre distance. Infact atmospheric optical communication (AOC) system using sub-carrier PSK was proposed by Japanese scientists W. Huang, J.Takayanagi, T. Sakanaka and M. Nakagawa [32]. They have studied an AOC system using 0.83μm wave which is modulated at 155.52 Mb/s DPSK over an 1.8 km outdoor path. They showed that the proposed system is superior to On-Off-keying (OOK) system. They have also studied AOC using sub-carrier M-ray PSK and multiple sub-carrier system. But AOC systems are strongly influenced by the attenuation and fluctuation of the transmitter optical power. In atmospheric optical intensity modulation the primary factor affecting the performance of the system is the intensity fluctuation. This is known as the log-normal scintillation, the PSK is more suitable than OOK because of the former's "0" threshold decision. Furthermore, PSK has a greater advantage in the capability of using M-ray PSK and multiple sub-carriers. This system can be only used where there is no obstruction in the line of sight. AOC system should be employed, for example for the link between skyscrapers. This system was also tested for QPSK, 8PSK (8 channels PSK) and 16QAM (16 channels QAM). The bit error rate (BER) of BPSK is about 3 dB, 7dB better than QPSK and 8PSK, respectively. Through the optimum BER of 16QAM is not worse then 8PSK. They have also observed that each time the channel numbers N are halved, the data rate per channel must be doubled, requiring at least a 1.5 dB increase in optical power to achieve the same signal to noise ratio (SNR). They have also shown that the experimental results of AOC system using DPSK have a very good agreement with the theoretical analysis for clear weather trasmission. As the carrier and the modulation of the RF signal can be controlled separately in RHD links, the link can perform three different radio-system functionalities depending on how the transmitter is constructed and operated.

1. A modulating link that modulates a low frequency signal, applied, onto a RF signal, delivered at the output at the link.

2. A frequency converting link that up-converts an intermediate frequency (IF) signal delivered at the output of the link. Reversibly, down-conversion is also possible.

3. A transparent link that transfers a RF signal from the input of the links to the output of the links without alteration.

All of these have been performed experimentally over 25 km of optical fibre without measurable distortion. Their results show QPSK and PSK signals typically required a rms. phase error of maximum 2.8^0 and 8.2^0 respectively. The effective system noise band width of 0.6 times the symbol rate, allows for QPSK operation at bit rates of up to 200Mb/s. PSK operation at bit rate of up to 290 Mb/s. In their experiment they had to lock the phase of the two lasers which are also very reliable. An acquisition range of 640MHz has been measured, and the average time (T_{av}) to cycle slip, is estimated to be 10^{11}s. This yields a probability of less than 0.3% for one cycle slip within ten years. Their experiments also show that PSK is less sensitive to phase noise than QPSK as expected.

Their experiment have demonstrated the efficiency, flexibility, and feasibility of this type of transmitter that also has the potential for both hybrid and monolithic opto-electronic integration.

4.15 Ultimate Capacity Of A Return-Channel Laser Diode In Transporting Multi-Channel Bust QPSK/16QAM Signals

A hybrid-fibre coax (HFC) system based on bi-directional CATV communication network relies on the performance of both downstream and upstream optical links. High power downstream optical fibre transmitters have been commercialised for a few years, and the fundamental capacity of a downstream distributed feedback (DFB) laser has also be studied. As for the upstream links future interactive application like internet access and telephony will require return channel lasers transporting multiple channels of QPSK or 16QAM channels. These interactive traffic may keep on growing, and it may become more economical to frequency division-multiplex several return channel bands (each occupying the conventional 5-40 MHz) before modulating a return-channel laser diode. By using this frequency stacking technique, fewer return-channel laser and up-link optical fibres can be used. P.Yang, B.H. Wang and I. Winston, [33]. Way have studied the ultimate-burst QPSK/16QAM channel capacity of an un-cooled / un-isolated Fabery-Perot (FP) and distributed feedback (DFB) laser is and how much clipping induced non-linear distortion (NLD) due to multiple collided medium access control of (MAC) channels a return-channels can tolerate. They have provided experimental, computer simulation, and analytical results to answer these questicns. They found that a typical FP or DFB laser can transmit more the 1000 QPSK or 10016QAM channels even in the presence of strong optical reflections, which causes poor relative intensity noise (RIN) level of –115 dB/Hz. Their results imply that a return-channel laser can tolerate significant channel collisions. For example, a return-channel can carry 80 QPSK signals with a optical modulation index per channel OMI/ch = 3.5% under normal condition, if

OMI/Ch is increased to 7% due to collided MAC signals (i.e. four collided users per channel), the system performance can still meet SNR ≅ 10^{-9} requirement. Their results from measurement, computer simulation and calculation show that the ultimate channel capacity of a strong dipped FP or DFB laser in transmitting multi-channel bursty QPSK/16QAM signals can be over 1000 and 100 respectively. The results have important implications to system transporting frequency stacking return-channel bands and / or using collision-based MAC channels.

4.16 The Impact Of Rayleigh Back Scattering Induced Noise On QPSK Transmission With Fabry-Perot Laser

For upstream CATV data transmission the error free range of the laser transmitter is an important design parameter for applications such as telephony and computer communication. This error free range is determined by a curve of BER versus input level. It is important for this range to be as wide as possible to account for variations in input level due to ingressing signals, thermal variation and network architectures. For a communication physical layer made of single mode fibre, it might be accepted that the noise portion of this curve would be limited by the design parameter of QPSK modulator demodulator pair. But D. Kerry and L. Violettehave [12] conducted a series of experiments, which show that this is not the case, and there is a significant BER penalty for a Fabry Perot (FP) laser. The penalty's root cause is the interaction of fibre with laser transmitter. They have shown through experiments that the fibre feedback due to Rayleigh scattering causes a destabilisation in the FP laser. The destabilisation causes sporadic noise in the laser diode that can dominate the BER performance and reduce the usable dynamic range by as much as 14 dB. The effect of this reduction is independent of the system design and for many systems the resultant dynamic range is quite acceptable. FP lasers can be used to transmit upstream data in a CATV environment. A dynamic range where BER is 10^{-8} for 15 QPSK signals of 30 dB has been shown. For applications that require a wider dynamic range, an isolator can be used to effectively recover BER penalty caused by Rayleigh back scattering.

4.17 Dispersion Compensation For Homodyne Detection System Using A 10 Gb/S Optical PSK-VSB Signal

Fibre chromatic dispersion limits the transmission distance of optical high-speed systems [16]. In an optical heterodyne detection system, the intermediate frequency region is occupied by electrically dispersive media such as micro-strip lines (MSL), coplanar lines and slot lines [17]. Generally, it is impossible to compensate for the fibre chromatic dispersion with an electrical dispersive medium in a homodyne detection system because of spectrum back-folding. However, using an optical single-side-band (SSB) signal realises chromatic dispersion compensation with an electrical dispersive medium because the optical SSB signal is detected without spectrum back-folding. The principle of the compensation technique was confirmed experimentally by using a standard phase shift (PSK) signal generated by a straight-line phase modulator [18], the optical phase of the standard PSK signal changes continuously and this causes instantaneous frequency shift at bit transition. If the electrical bandwidth is not much broader then the bit rate, due to frequency shift, severely degrades the performance of optical SSB and vestigial-side-band (VSB) filtering systems because they reduce the frequency compensations on one side of the spectrum. K. Yonenaga and S. Norimatus [19] have demonstrated fibre chromatic dispersion compensation in optical homodyne detection system using a VSB filtered optical PSK signal. They have used VSB filter because it is easy to use. A 10 Gb/s optical PSK-VSB signal is transmitted with an optical carrier through a 126 km conventional single mode fibre. Penalty free transmission is achieved by fibre chromatic dispersion compensation in the base band with a 10 cm micro-strip lines.

4.18 The Performance Of A Coherent Residual Carrier PSK System Using Hybrid Carrier Phase Synchronisation

The hybrid loops are characterised by two not necessarily equi-probable lock points (one at zero phase error and one at 180^0 error). It is necessary to take this phenomenon into account for prediction of their performance. As such a new form of solution for the phase error probability density is proposed by M. Simon H. Tsou, S. Hinedi and K. Hamadan [20]. Their solution is based on the Zakai equation, using this mathematical module, the mean-square phase error of the hybrid loop is derived and numerically compared with the results obtained form a computer simulation. Two methods of solving the inherent 180^0 phase ambiguity associated with using a hybrid loop for carrier synchronisation are discussed and the corresponding average error probability performances of an associated PSK system are evaluated. Their theoretical results show that by making use of the total power available in the received signal for purposes of carrier synchronisation, a hybrid loop can provide an improved tracking and average bit error probability performance relative to that achieved by the more conventional Costas loop or phase-locked loop. In assessing the performance of the system, however, one must take into account the fact that, for values of modulation angles larger than a certain critical value, the hybrid loop can lock at both 0^0 and 180^0 . Phase error with probabilities dependent on the modulation angle itself, as such one must either employ differential encoding / decoding or provide a method for solving this phase ambiguity, such as the data stream. It is also important to properly choose the relative gain in the two arms (discrete carrier and side band) of the hybrid loop since, depending on the value of the modulation angle, the loop performance can be quite sensitive to this gain setting [35]. They have also pointed out that the actual loop SNR for the hybrid loop as measured by computer simulation and analytically is not equal to the sum of the SNRs for the PLL and the Costas loop components as suggested by R. Sfeir, S. Auirre and W.J. Hurd [21].

4.19 A Method For Evaluating MPSK Performance Using M/2 PSK Signal Set

Satellite communication plays an important role and as data demands on existing satellite system increases the need to evaluate more bandwidth efficiently modulation schemes such as M-ray phase shift keying (MPSK) become important. However, the unavailability of higher order modem operating at higher rates and testing purposes can make evaluation difficult. In 1995 New Mexico State University [22], with the help of NASA, developed a method of evaluating the performance of 8PSK in a satellite channel using a QPSK signal set. This technique can be generalised for any (M/2) PSK signal set to evaluate MPSK modulation. This method allows a higher data rate modulation scheme without the need for a high rate 8PSK modem. Such an approach only allows approximation to the performance of a true MPSK system. However, due to the dominance of nearest neighbour error at high signal to noise ratios the approximation is excellent at the error rate of interest. This technique cannot be use for non-linear channels but with modification. It is found even in case of worst case transitions very transitions very little degradation in the approximation occurs.

4.20 Novel Fiber Optic BPSK And QPSK Modulation Links

Two novel fibre BPSK modulation techniques were proposed by H. Ogewa, K. Horikawa and Y. Nakaska [23]. In their technique they used two laser diodes (LD), two photodiodes (PD), two external optical modulators (EOM).

Fig. 4.1 shows that configuration of the proposed links. LD modulation link depicted shows the arrangement of two laser diodes, two photo-diodes, a microwave switch and a hybrid circuit. The radio frequency (RF) signal is first switched by the modulating digital signal. The schematic behaviour of the LD modulation time is also shown in Figure 2. The switch RF signals (sequence A and B) intensity modulates the LDS. The detected RF signals are combined by the 180^0 hybrid circuit. Thus the BPSK signal is output by the hybrid circuit.

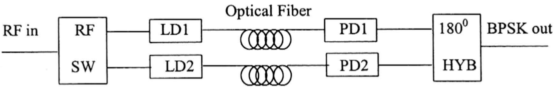

Fig. 4.1 BPSK Modulation link configuration.

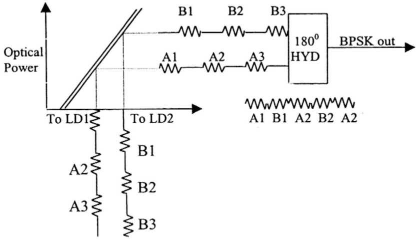

Fig. 4.2 Schematic behaviour of LD modulator link

The radio frequency (RF) signal is first switched by the modulating digital signal. The schematic behaviour of the LD modulation time is also shown in Fig. 4.2. The switch RF signals (sequence A and B) intensity modulate the LD. The 180^0 hybrid circuit combines the detected RF signals. The hybrid circuit outputs the BPSK signal.

Similarly QPSK is also possible by driving Four laser diodes separately and then combining them. This kind of PBSK and QPSK modulation is limited by the LD performance. However, the EOM modulation link can handle RF frequencies up to the limits of EOM modulation capacity. These experiments are done only at UHF bands. The links can be expected to transmit millimeter wave modulated signals by choosing high speed optical devices.

4.21 The Influence Of Cross-Phase Modulation On Optical FDM PSK Homodyne Transmission Systems.

Waveform degradation in the fibre limits the transmission distance which determines the size of an all optical network area. Among optical coherent detection, binary phase-shift keying (BPSK) homodyne detection offers the best sensitivity of any binary signalling technique. It is suitable for multi-gigabit long-distance transmission system. BPSK homodyne detection is also suitable for FDM systems because it reduces the channel spacing more than heterodyne detection. There are various types of fibre non-linearities that affect the performance of an FDM BPSK homodyne detection system, such as

i. Raman Scattering

ii. Stimulated Brillouis

iii. Four wave mixing

iv. Phase noise induced by amplifier

v. cross phase modulation (XPM).

The influence of stimulated Raman scattering or four-wave mixing depends on the channel spacing, however the influence of XPM becomes dominant as the number of channels increases. When an optical amplitude change occurs in optical WDM systems, this change modulates the signal phase due to XPM and degrades the bit error rate performance. XPM does not require the phase matching, essential for four-wave mixing therefore XPM occurs with any frequency allocation in a WDM system. The fibre chromatic dispersion can cause self-amplitude modulation after transmission over a certain distance and if the amplitude modulated WDM signals are amplified by the amplifier and then transmitted, the amplitude changes in the optical signals modulate the signal phase. Usually the optical amplitude fluctuation is assumed to arise from the rms power fluctuation of the laser diode. However, the data-dependent optical amplitude change resulting from the non-ideal phase modulation from PM-AM conversion causes the error rate performance of the phase sensitive receiver to degrade for a different reason. The XPM influence on a WDM-PSK homodyne detection system depends on optical fluctuation in two ways, one is the amplitude fluctuation caused by modulation due to the fibre chromatic dispersion and other is due to phase modulation[38]. Both cases have been studied theoretically and experimentally [24]. S. Norimatsu and K. Iwashita have shown that there is a PM-AM conversion due to higher order fibre chromatic dispersion even it the optical that of the message. The former system is suitable for long haul applications while the latter for LAN and MAN.

The second problem arises from the optical transmission medium which is actually a two-polarisation mode light wave so that the input light state of polarisation undergoes unpredictable fluctuation during propagation because of random mode coupling due to external perturbation such as mechanical stress and temperature changes. As the received signal and the local oscillator must be polarisation matched this poses considerable problems. In order to give the best sensitivity while the optical signal SOP at the receiver is time varying, the receiver is to be protected against such fluctuations. Polarisation maintaining fibre could be used, however such a solution is not cost effective and could pose quite severe requirements on the rotation alignment tolerance in the splices. Totally automatic polarisation control is difficult to be achieved because of the discontinuities in the polarisation tracking when applying mechanical devices. More over if integrated optics devices are used, high driving voltages should be foreseen to provide phase changes in excess of 2π. A different approach to overcome the polarisation fluctuation problem consists in using polarisation diversity receiver proposed for the first time by Glance for DPSK system [26], in which two linear components are presented separately and added after demodulation, which has been applied in DPSK [27], is affected by a limited penalty with respect to the conventional scheme, which is an order of 0.5 dB in the absence of phase noise. The other method that can be used in which the transmission of a reference signal is derived form transmitting an optical source and suitably frequency shifted with respect to the phase modulation signal permits practical insensitiveness to the phase noise. More compatibility with the use of polarisation independent detection scheme makes the system independent of state of polarisation fluctuation.

There is another class of system based on the property that orthogonal polarisation state are antipodal in the Stoke vector space. Because the phase-noise process is simultaneously present in both the polarisation states can prevent the Stokes parameters turn out to be independent of it so that system is widely insensitive to phase noise. Measuring the position of its representative point on the Point care sphere makes the decision on the transmitted bit. Such requirement has led to the differential Stoke parameter shift keying (DSPSK) [28] in which a criterion is adopted based on the measure of distance between points corresponding to adjacent time slots. This system no longer needs an adaptive polarisation control and permits instantaneous polarisation fluctuation compensation. The property of conventional single mode optical fibre to preserve at its output orthogonality between input SOP allows estimation of the transmitted SOP by pure feedback electronic processing. The Stokes parameters [29] results is independent of phase-noise process which is simultaneously present in both the polarisation components so that the system is widely tolerant to laser phase noise.

4.23 A Packaging Technique For An Optical 90^0 –Hybrid Balance Receiver Using A Planar Lightwave Circuit

A new technique has been developed for packaging an optical 90^0-hybrid balanced receiver using a silica-based planar lightwave circuit (PLC) [30]. A fabricated receiver module achieved a 14 GHz broad-band frequency response and the required error rate is performed for 10 Gb/s BPSK homodyne detection. This receiver has two optical inputs and two electrical output ports. It consists of a silica-based PLC as the optical couplers, two polarisation beam splitters, two GRIN rod lenses, and two photo-receivers that each have a preamplifier and twin PIN photodiodes (PIN-PD). The frequency response of the receiver exceeded those of the preamplifier and twin PIN-PD's because of the peaking effect at 14 GHz due to improving the dc bias circuits of the impedance-matched film (IPF) carrier. As a result, this receiver achieved 10Gb/s BPSK homodyne detection [37]. This packaging technique should be very useful for future wide-bandwidth and high-speed optical transmission systems.

4.24 Phase Noise Insensitive Multilevel Polarisation Shift Keying Based On Quadrature Amplitude-Modulation Mapping In Coherent Optical Systems

A new multilevel polarisation shift keying (POLSK) coherent optical system, based on quadrature-amplitude-modulation (QAM) mapping was proposed [31,37]. It is found that the proposed system is insensitive to the laser phase noise and has no power penalty and no floor in the BER performance in spite of multilevel transmission. Furthermore, the proposed system gets good sensitivity gain with increasing number of levels M, compared with conventional PSK and QAM for existence of laser phase noise. Therefore, this system can realise multilevel transmission and improve the single-channel bandwidth in coherent optical communication. It is also found that in the case of M = 16, for sensitivity penalty less than 1 dB. Control tracking error θ should be less than 3^0 and this requirement becomes severely with increasing the number of levels M.

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