Cyclic Prefix and Intra-fix Insertion for Frequency-domain Equalization(FDE) of Shaped-Offset QPSK

By

Salman Fayyaz Khan

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Supervisor

Dr. Sajid Saleem

NUST-SEECS

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Approval

It is certified that the contents and form of the thesis entitled "**Cyclic Prefix and Intra-fix Insertion for Frequency-domain Equalization(FDE) of Shaped-Offset QPSK**" submitted by **Salman Fayyaz Khan** have been found satisfactory for the requirement of the degree.

Advisor: **Dr. Sajid Saleem**

Signature: ________________
Date: ____________________

Committee Member 1: **Dr.Adnan Khalid Kiani**

Signature: __________________
Date: __________________

Committee Member 2: **Dr.Hassaan Khaliq Qureshi**

Signature: __________________
Date: __________________

Committee Member 3: **Dr.Syed Ali Hassan**

Signature: __________________
Date: __________________

Dedication

I dedicate this to my Parents.

Abstract

In this research, we consider the problem of cyclic block construction for (FDE) of SOQPSK using an intra-fix segment in addition to the cyclic prefix. We propose a novel procedure to compute the intra-fix symbols for both SOQPSK-MIL and SOQPSK-TG waveforms used in aeronautical telemetry. The proposed method is employed to generate an exact cyclic signal, which is a requirement for implementation of FDE at the receiver. The trellis of SOQPSK-TG signal is very complicated (512 states) because of its partial-response characteristic. We identify that the required number of symbols to generate an exact cyclic signal are unreasonably large for SOQPSK-TG (9 symbols per block). Thus, we also propose an approximate technique that utilizes only dominant Laurent pulses to help reduce the length of intra-fix upto 2 symbols. A detailed numerical evaluation of this approximate technique is performed to study the trade-off between the reduction in the intra-fix length and the deviation from constant envelope of the generated signal.

The trellis of SOQPSK-TG signal is very complicated (512 states) because of its partial-response characteristic. We identify that the required number of symbols to generate an exact cyclic signal are unreasonably large for SOQPSK-TG (9 symbols per block). Thus, we also propose an approximate technique that utilizes only dominant Laurent pulses to help reduce the length of intra-fix upto 2 symbols. A detailed numerical evaluation of

this approximate technique is performed to study the trade-off between the reduction in the intra-fix length and the deviation from constant envelope of the generated signal.

Certificate of Originality

I hereby declare that this submission is my own work and to the best of my knowledge it contains no materials previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any degree or diploma at National University of Sciences & Technology (NUST) School of Electrical Engineering & Computer Science (SEECS) or at any other educational institute, except where due acknowledgement has been made in the thesis. Any contribution made to the research by others, with whom I have worked at NUST SEECS or elsewhere, is explicitly acknowledged in the thesis.

I also declare that the intellectual content of this thesis is the product of my own work, except for the assistance from others in the project's design and conception or in style, presentation and linguistics which has been acknowledged.

Author Name: **Salman Fayyaz Khan**

Signature: ________________

Acknowledgment

Up and above everything all glory to **ALMIGHTY ALLAH**. The Beneficent, The most Merciful and Most Compassionate. It's a great blessing from Almighty Allah that gives me the health and strength to do this research work.

I would like to special thank the Supervisor **Dr.Sajid Saleem**

Salman Fayyaz Khan

Contents

List of Abbreviations

Abbreviations	**Descriptions**
CPM	Continuous Phase Modulation
ARTM	Advanced Range Telemetry Group
SOQPSK	Shaped Offset Quadrature Phase Shift Keying
SOQPSK-TG	Shaped Offset Quadrature Phase Shift Keying - Telemetry Group
GSM	Global System For Mobile Communication
RCC	Range Commanders Counil
QPSK	Quadrature Phase Shift Keying
GMSK	Gaussian Minimum Shift Keying
AWGN	Additive White Gaussian Noise

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Chapter 1

INTRODUCTION

Digital communication use wired or wireless link for the transmission of bits. The data which is sent over the channel is converted in the form of bits. The task of converting binary data into signal waveform is assigned to the modulator which performs modulation. In communication systems, modulation is referred to varying one or more than one properties of a transmitted signal, called carrier signal. The carrier has the information which is transmitted over the channel. The transmitted bits introduce noise when received at the receiving station. Receiver demodulates the incoming signal. The noise introduced by the chnnal is called AWGN) [1]. Communication society make use of AWGN as default noise introduced by the medium. CPM belongs to the family of digital modulation schemes. It is a constant-envelope and bandwidth-efficient modulation scheme that is used in many well-known standards defined for cellular, personal, and satellite communications [2], [3], e.g., GSM [4], Bluetooth [5], IRIG 106. The constant-envelope nature of CPM allows a simple and efficient class-C amplifier, while the continuous phase property introduces memory in the waveform and thus a complicated receiver is needed for demodulation. These two aspects of CPM waveform make it particularly well suited for aeronautical telemetry, where transmitter power is a limited resource and complexity can be afforded at the ground station receiver.

SOQPSK have two variants, SOQPSK-TG and SOPQSK-MIL. Both variants belongs to the family of CPM schemes, maintained by ARTM and standardized in IRIG-106. SOQPSK-TG is widely used for commercial, military, strategic and aeronautical telemetry. It has data rates up to 10Mbits/20Mbits. SOQPSK is standardized by IRIG 106 as a Tier-I modulation scheme. SOQPSK-TG is a partial response waveform due to inherent memory while SOQPSK-MIL is a full response with no inherent memory. The applications of both schemes are almost same, but the limitation of SOQPSK-MIL having less number of states as compared to its variant (SOQPSK-TG) makes it limited. The problem of SOQPSK-TG is inherent memory. Though it has been widely implemented and used by telemetry group because of less complexity at the transmitter. SOQPSK-TG ensures transmitter with least complexity because of the limited resource available for a transmitter, where as ground station can be very complex due to multipath and channel fading. Ground station has to do all the demodulation and equalization of the received signal. The ground station in SOQPSK-TG is fairly complex.

1.1 Background

CPM has applications in aeronautical telemetry, its main advantage that differentiate and makes it favorite in research community is its continuous phase and limited power usage. CPM was first discussed in [2]. The aeronautical telemetry has been benefiting from CPM flavors in many ways. Aeronautical telemetry has been using both SOQPSK variants. These variants of CPM are standardized by RCC maintained by ARTM in IRIG-106.

There is an increasing demand for data rates in all areas of wireless communications, aeronautical telemetry is no exception. Modern air-crafts support large number of sophisticated sensors on-board and this has led to an increase in the data rate and consumed bandwidth [6]. This trend in the data rates is making the aeronautical channel increasingly frequency selective. Telemetry demand increasing bandwidth while supply the of the bandwidth has been decreasing (Bit rate in Kbps). In other words, the delay spread of the channel introduces significant inter symbol interference (ISI), the effect of which must be equalized at the receiver prior to the detection. Frequency-domain equalization (FDE) offers significantly lower complexity than Time-domain equalization (TDE) [7], and it has been recently used to equalize the aeronautical channel for both Tier-I [8] and Tier-II [9] ARTM waveforms. The trends for aeronautical telemetry can be seen in fig.1.1.

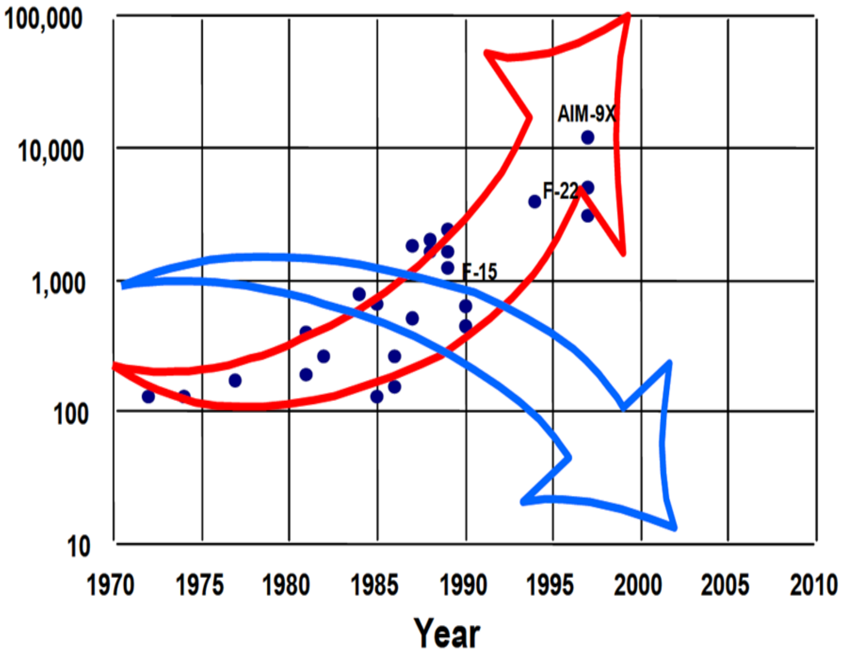


Figure 1.1: Telemetry demand increasing while supply decreases (Bit rate in Kbps)

Frequency-domain equalization requires the use of a cyclic signal for the duration of a transmitted block, which is achieved simply by use of a cyclic prefix for linear modulation schemes [7]. However, for non-linear modulation schemes such as SOQPSK, an additional segment of symbols, named as intrafix, is required for the signal to attain the cyclic property. This problem has been considered in detail for both single-h [10] and multi-h CPM [11] schemes. However, the SOQPSK techniques, i.e., SOQPSK-MIL and SOQPSK-TG use a pre-coder for binary to ternary conversion of the input symbols in addition to a CPM modulator and the above cited approaches are not directly applicable.

1.2 CPM/SOQPSK Applications

The applications of CPM are found in many areas of Communication and Military. The following are applications of CPM;

1.**Aeronautical telemetry**

The use of CPM in Aeronautical telemetry is no new it dates back to late 1970s. An increasing demand for data rates in all areas of wireless communications has been seen over the last decade , so is the case for aeronautical telemetry. Modern commercial and defense air-crafts support a large number of sophisticated sensors on-board and this lead to an increasing demand for the data rates resulting in more bandwidth. The new state of the art airlines support large power on board these days and the ground station is resourceful.

2.**Military and Satellite Communications**

Military and Satellite Communication use CPM as first preference to choose from digital modulation schemes. Military grade communication are really very delicate and important in the context of warfare, so that makes use of CPM first choice because of the inherited advantages over other modulation schemes. Satellite communication ground station has the full resource to send, generate, regenerate and decode the received signal, but the satellite itself is not much resourceful as ground station, which makes CPM the first choice in this regard.

Figure 1.2: Satellite Communication using CPM/SOQPSK

Figure 1.3: Military Communication using CPM/SOQPSK

3.**Cellular Communications**

Cellular communication has been using the CPM flavor in one of the most successful deployed technology in cellular networks. Global System for Mobile Communication originally Groupe Spcial Mobile (GSM) sometimes referred as 2nd Generation mobile communication. GSM is based on GMSK supporting the data rates of 50-60 kbps in downlink while 5-10 kbps in uplink. The huge success of first digital wireless cellular network communication GSM, lead to increasing demand of high data rates. An upgraded version of GSM named as Enhanced Data rates for GSM Evolution or EGPRS was released providing higher data rates in the Uplink and Downlink for the user. [12]

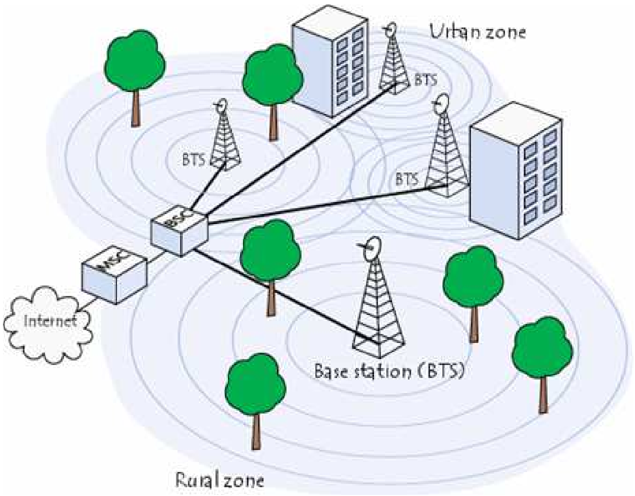


Figure 1.4: Cellular Communication using CPM/GMSK

4.**Personal-area Networks**

The use of CPM in PANs can be seen in Ad-hoc networks. These type of networks are created on the fly having no fixed infrastructure (backbone). Ad-hoc network is also called decentralized network. One of the application of CPM in Ad-hoc networks is Bluetooth (Low Energy) [13], [5]. Each node in the network act as a router and forwards the packet for the next hop. Some common routing protocols used in Ad-hoc routing are AODV v1, AODV v2, DSR, DSDV etc. SOQPSK is mainly used in Bluetooth, maintained and standardized as IEEE 802.15.1.

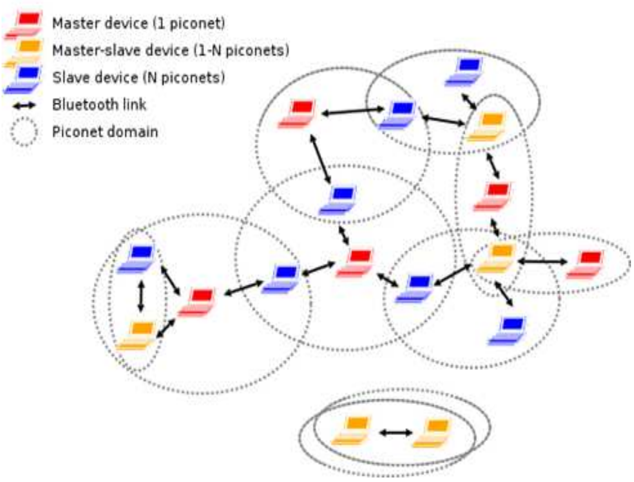


Figure 1.5: Personal Area Networks using CPM

1.3 CPM/SOQPSK Signal Model

The complex envelope of a CPM waveform is given by

$$s(t, \mathbf{x}) = \sqrt{\frac{E}{T}} \exp j(\phi(t, \mathbf{x}) + \phi_o), \quad t \leq nT, \tag{1.1}$$

where E is the energy per symbol, T is the symbol interval, and ϕ_o is a constant phase term. ϕ_o can be ignored if phase synchronization is assumed. The time-varying phase $\phi(t, \mathbf{x})$, also called the excess phase, is defined as

$$\phi(t, \mathbf{x}) = 2\pi h \sum_{i=-\infty}^{n} x_i q(t - iT), \quad t \leq nT. \tag{1.2}$$

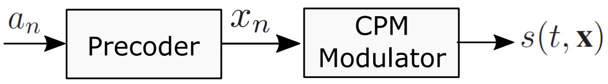


Figure 1.6: Modulator for SOQPSK-TG

Here h is the modulation index and it is taken as $\frac{1}{2}$ for both SOQPSK-TG and SOQPSK-MIL. The symbols x_n are chosen from a ternary alphabet $(M = 3)$ for regular CPM, defined as $\mathbb{M} := \{-1, 0, +1\}$. Together these symbols x_n constitute the sequence $\mathbf{x} = \{x_0,\ x_1,\ \ldots,\ x_n,\ \ldots\}$. The SOQPSK is different from the regular CPM because the symbols are not uniformly chosen from the alphabet $\{-1, 0, 1\}$. Instead, the symbols x_n are generated by a pre-coder [14] with input $a_n \in \{0, 1\}$ and the output given by

$$x_n = (-1)^{n+1} \left(2a_{n-1} - 1\right) \left(a_n - a_{n-2}\right). \tag{1.3}$$

Fig 1.6 shows the modulator of SOQPSK. The frequency shaping function $f(t)$ is known as the derivative of phase shaping function $q(t)$ in (1.2). The phase shaping function $q(t)$ satisfies the following constraints. It is non-zero only for positive time, increases to $\frac{1}{2}$ during the interval $[0, LT]$, and stays constant beyond $t = LT$, where L is a positive integer that determines the memory of the CPM scheme. Modulation schemes with $L = 1$ are called full response, whereas those with $L > 1$ are called partial-response schemes. The SOQPSK-MIL is a full-response $L = 1$ scheme with the frequency shaping function $f_{\mathrm{MIL}}(t)$ defined as

$$f_{\mathrm{MIL}}(t) = \begin{cases} \frac{1}{2T}, & 0 \leq t < T. \\ 0, & \text{otherwise.} \end{cases} \tag{1.4}$$

The SOQPSK-TG is a partial response scheme with $L = 8$ and frequency shaping function $f_{\mathrm{TG}}(t)$ given by

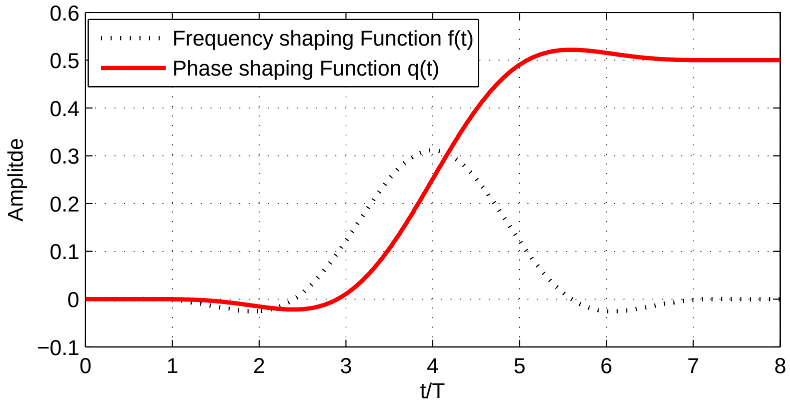


Figure 1.7: Phase and frequency shaping functions for SOQPSK-TG modulation scheme. The partial response length L=8 for this waveform.

$$f_{\mathrm{TG}}(t) = A\frac{\cos\left(\frac{\pi\rho B\tau}{2T}\right)}{1-4\left(\frac{\rho B\tau}{2T}\right)^2} \times \frac{\sin\left(\frac{\pi B\tau}{2T}\right)}{\frac{\pi B\tau}{2T}} \times w(\tau)|_{\tau=t-4T}, \tag{1.5}$$

where the window function $w(\tau)$ is given by

$$w(\tau) = \begin{cases} 1, & 0 \le \left|\frac{\tau}{2T}\right| < T_1 \\ \frac{1}{2} + \frac{1}{2}\cos\left(\frac{\pi}{T_2}\left(\frac{\tau}{2T} - T_1\right)\right), & T_1 \le \left|\frac{\tau}{2T}\right| < T_1 + T_2 \\ 0, & T_1 + T_2 < \left|\frac{\tau}{2T}\right|. \end{cases} \tag{1.6}$$

The parameters are chosen as $T_1 = 1.5$, $T_2 = 0.5$, $\rho = 0.7$, $B = 1.25$. Finally, the constant A is assigned a value such that $\int_{-\infty}^{\infty} f_{\mathrm{TG}}(t)dt = \frac{1}{2}$. The phase and frequency shaping functions for both waveforms are plotted in Fig.1.7

1.4 Problem Statement

SOQPSK-TG is a type of CPM, a bandwidth efficient digital modulation scheme. To generate cyclic signal for SOQPSK-TG, equalization is required, frequency domain equalization is the only choice for that. Exact trellis termination along with cyclic signal block generation in FDE for SOQPSK is a problem. Trellis of the SOQPSK has 512 states, the number of symbols required for exact termination along with cyclic signal block generation have not addressed in research community. SOQPSK-TG and SOQPSK-MIL trellis may look same but they are not connected to each other anyway. SOQPSK-MIL is referred to full response waveform with no inherent memory, while SOQPSK-TG has binary to ternary data and CPM modulator, which leads to partial response waveform and inherent memory. SOQPSK-TG is seen as partial response shifted version of QPSK as ternary CPM.

1.5 Thesis Contributions

All contributions of our work are summarized as follows

- Terminate trellis of SOQPSK.
- Generate Cyclic Signal Block.
- Devise method that terminates trellis exactly and generate cyclic signal block with minimum symbols used in intra-fix block.
- Approximate technique that uses Laurent decomposition and providing trade-offs between number of symbols and pulses.

1.6 Thesis Organization

The literature of work has been given in Chapter 2. The techniques which have already been proposed in this this area, their limitations and state of the art. Chapter 3 covers the implementation and generation of cyclic signal block along with trellis termination. Moreover, the approximate technique for approximation is also well studied when the pulses and symbols for cyclic block has to be minimal. In Chapter 4, the numerical and simulation results are given along with detailed discussions. All the signal Models have been simulated using Matlab2013a with respect to different parameters standardized for waveforms generations.

Chapter 2

LITERATURE REVIEW

CPM has been favorite in telemetry community since 1980s. We have seen that CPM has clear advantage over other modulation schemes where continuous envelope and low power transmitter is the choice. The research community has been favoring CPM due to its bandwidth efficient property. The phase of the signal shifts smoothly from one symbol transmission to another as function of frequency pulse. This continuity of signal transmitted over Additive Wide Gaussian Noise channel(AWGN) make certain that the signal is constant envelope that ultimately reduces the spectral regeneration, and it ensures no signal distortion due to non-linearity in high power amplifiers [15]. SOQPSK is an exceptionally bandwidth efficient modulation scheme. Likewise with conventional offset QPSK (OQPSK), the information transmissions on the inphase (I) and quadrature (Q) channels are offset considerably by half symbol duration. In this way, there are no prompt 180 phase variations and a higher level spectral containment results [16]. The fundamental property that makes SOQPSK bandwidth efficient over OQPSK is constant envelope and continuous phase rather than instantaneous phase shits. SOQPSK belongs to the family of CPM [2]. SOQPSK has been joined into military and aeronautical telemetry measures, albeit more extensive utilization is justified since it is appropriate in any setting where bandwidth efficiency and continuous phase is the required. More foundation data and different perspectives on SOQPSK can be found in [17] and the references there in.

Single carrier frequency domain equalization (SCFDE) has been recognized as a successful way to deal with the frequency selectivity of a transmission channel [7]. SCFDE is a block based approach that exploits low complexity Fast Fourier Transform (FFT) calculations at the receiver, and obliges that the transmitted signal have a cyclic property. SCFDE has been connected to single-h CPM [18] [19] [20] [21], where it was recognized that the insertion of Cyclic Prefix (CP) alone is not adequate to ensure a cyclic prefix block. The utilization of a segment an intermediate called an intra-fix [21] (or tail [18]) has been prescribed to drive the transmitter to achieve an obliged state at the predetermined moment in the block. The methodology proposed by [21] is the most advanced of all, as it obliges the utilization of a solitary intra-fix block using minimum number of symbols. In addition, the required symbols in the intra-fix are autonomous of the past transmitted blocks.

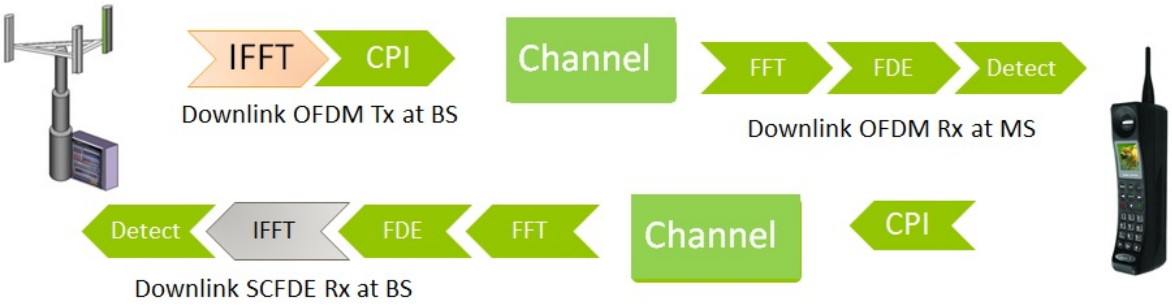


Figure 2.1: SCFDE Vs OFDM

2.1 Detection Schemes

In [16] authors have proposed reduced complexity detection scheme for SOQPSK. A Pulse Amplitude Moduation (PAM) based detector is utilized that is essentially for binary schemes, however their work is expansion to ternary cases. Their work is coordinated towards the detection of the transmitted signal. SOQPSK has two variants. SOQPSK-MIL is a full response waveform while SOQPSK-TG is partial response having inherent memory. SOQPSK-TG comprises of 512 states [16], so as to terminate each and every state of SOQPSK-TG is very complicated. For that authors proposed a method which is an acceptable answer for the issue of high spectral efficiency and low receiver complexity. The PAM-based detector is ideal on account of full-response SOQPSK-MIL. While for the instance of SOQPSK-TG, authors have measured the method as being sub-ideal by one tenth of a dB. A superior estimate accommodated SOQPSK-TG.

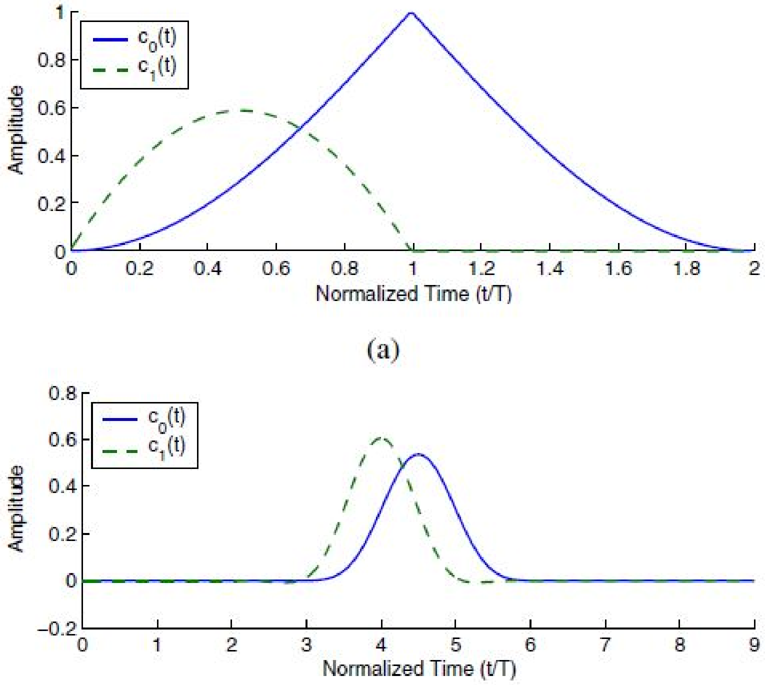


Figure 2.2: Two principal pulses for the PAM representation of (a) SOQPKS-MIL and (b) SOQPSK-TG

In [22] authors have proposed reduced-complexity methodology for the detection of coded SOQPSK. An expression is formulated for a recursive parallel to ternary pre-coder for SOQPSK. The recursive way of this detailing is needed for SOQPSK when linked in a serial frameworks. The proposed detector are ideal in the full-response case, and are close ideal in the fractional response case because of some extra complexity nature reducing approximation. In all cases, the proposed detectors accomplish substantial coding increases for serially connected coded SOQPSK. These increases are like those reported as of late by [17], which were acquired utilizing a more confounded cross-connected trellis coded quadrature balance (XTCQM) interpretation. This perspective alone created basic detector for full-response SOQPSK-MIL.

For SOQPSK-TG, the CPM perspective permits the utilization of surely understood methodologies for lessening the complex nature of partial response CPM. The utilization of two such methods: the PAM approximation and frequency PT. The authors make claim in their work SOQPSK-TG and SOQPSK-MIL was unique consideration, the reduced complexity nature detectors are general and can be utilized for all forms of SOQPSK. Their work need in trellis end for both instances of SOQPSK and their work is entirely constrained to the coded SOQPSK recognition.

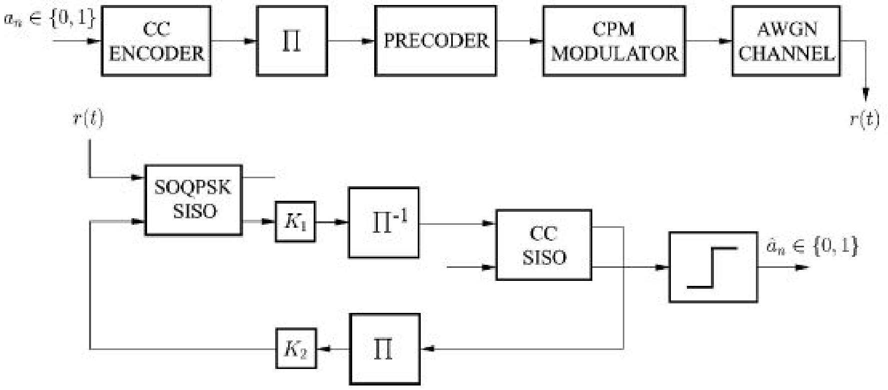


Figure 2.3: Serially concatenated coded SOQPSK

In [8] authors have created Single Input Single Output SISO antenna system with SOQPSK-TG utilizing a linear (SCFDE) method. Using linear SCFDE with Maximum Likelihood (ML) channel estimation shows extraordinary performance in overall Bit Error Rate. Simulation results of the authors exhibit that three samples for each bit at the receiver are sufficient to accomplish the best BER execution. Aeronautical telemetry is the correspondence down-link of test estimations from an airborne stage or resource for a ground receiver. When a strong single bounce multipath interference is accompanied by Line of Sight waveform, receiver detection performance deteriorates exponentially. In this work authors have demonstrated that linear MMSE SCFDE executed particularly for SOQPSK-TG can considerably enhance BER execution for the aeronautical telemetry application. The outcomes additionally show that three samples for every bit at the receiver are adequate to accomplish the best BER execution taking after linear MMSE equalization..

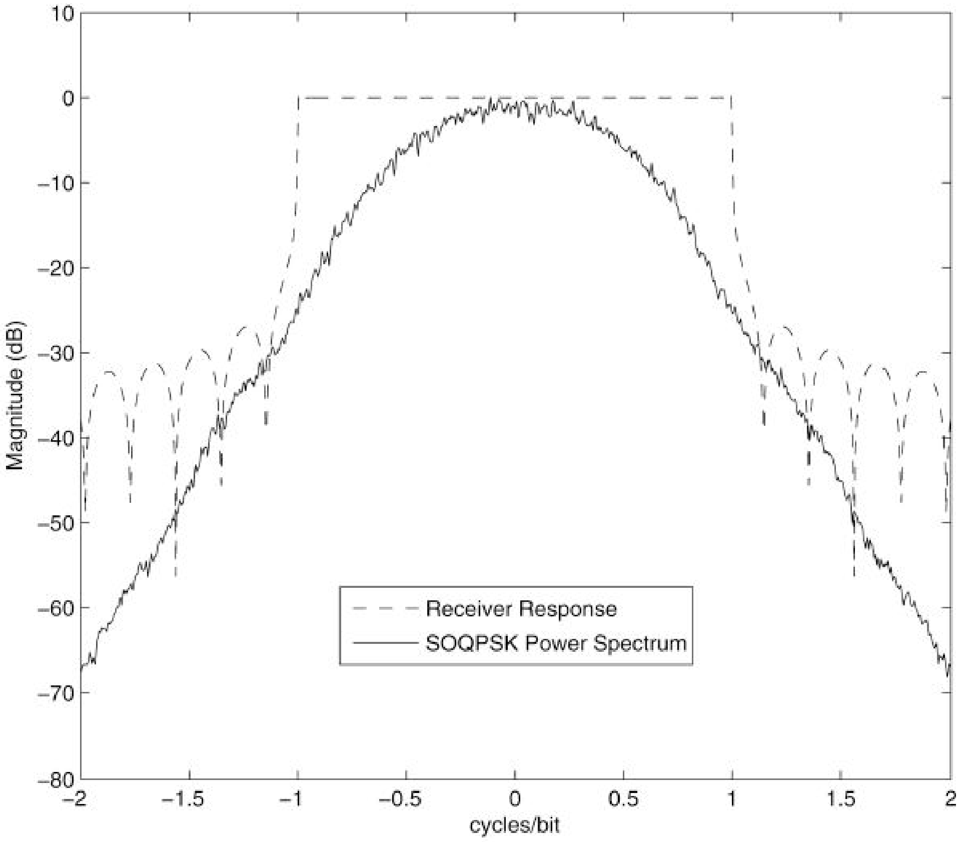


Figure 2.4: Normalized PSD for SOQPSK and receiver filter response

In [23] authors have worked at the receiver for the detection of SOQPSK. Their work is to a 2-state detector for SOQPSK variants. The complexity of the states is addressed and minimized by 4 to 2 with asymptotically optimum performance. They make use of two methodologies for this proposed strategy:

Pulse Truncation (PT) and the Pulse Amplitude Modulation (PAM). Their method yields in noteworthy results since trellis-based SOQPSK detectors are 1-2 dB better than generally deployed symbol-by symbol detectors. Their straightforward identification plan is upheld where low complexity and high performance is obliged to address the issue of insignificant power and expense. The 2-state detector proposed by authors demonstrates that the performance of 2-satate and 4-state detector is asymptotically comparable. The outcome is adequate in light of the fact that the level of complexity of 2-state detector yields in insignificant complexity.

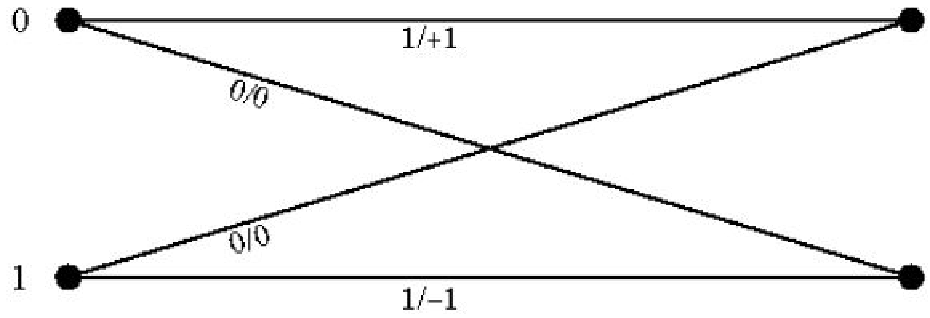


Figure 2.5: 2-state trellis representing differential precoder

2.2 Trellis Termination of multi-h CPM

In [24] the authors have developed symbol block to generate a cyclic multi-h CPM signal which is the the requirement for FDE at the receiver. As in [16] the authors have developed intra-fix for SOQPSK-TG which is partial response having inherent memory. The authors have developed the intra-fix for multi-h CPM such that each transmitted block following an intra-fix block at the transmitter. The authors have proposed a novel procedure that determines the intra-fix symbols, such that the intra-fix length is minimized.

The constraints on the required intra-fix symbols are shown to form a set of Linear Diophantine Equations (LDEs). The proposed technique is intended to be applied to dual-h variants of the CPM. An efficient procedure has been proposed to construct the cyclic block at the transmitter. It results an intra-fix having minimum length. The constraints that fall in the structure and intra-fix symbols are studied. The former is a function of the number of modulation indices, and the latter depends upon the rational modulation indices and the modulation alphabet size. The intra-fix length for multi-h CPM is usually smaller compared to similar single-h CPM schemes. An example dual-h scheme was discussed to illustrate the proposed approach. Their work lacks for the case of single-h cpm as the authors haven't addressed trellis termination for SOQPSK and the precoder states have not been addressed in their research.

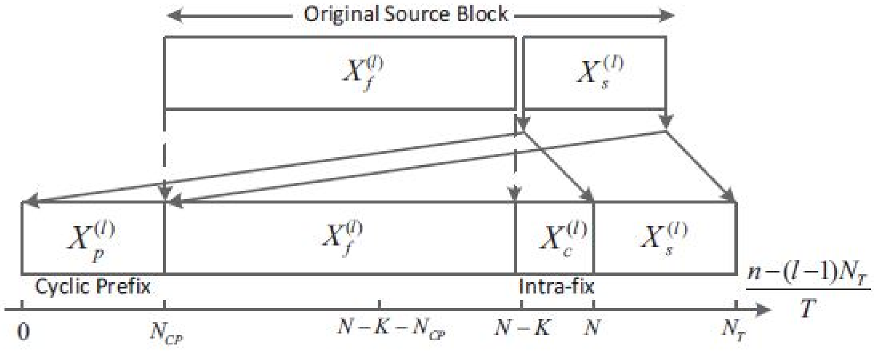


Figure 2.6: Structure of Cyclic block for SOQPSK

In [25] authors propose termination technique for multi-h CPM. Their work demonstrates that tilted stage trellis for multi-h CPM signs is occasional and empowers the representation of the multi-h CPM modulator as a course of an intermittent recursive Continuous Phase Encoder (CPE) and a Phase Modulator (PM). Their work additionally incorporate to terminate trellis in least number of symbols and set up a connection of its solution with the Diophantine Frobenius Problem (FP). Their study shows that the termination state relies on upon the accompanying: initial condition of pre-coder, the set of modulation index used, the order of CPE memory, and the number of bits used per modulated symbol. Their proposed issue for the termination be seen as traditional number theory problem connected to Frobenius Problem. Different limits on the length of the terminating sequence were likewise proposed and demonstrated diagnostically. Authors have included samples for single-h and multi-h CPM which covers terminating symbols sequences, as well as distinctive logical expression can be decided to figure the terminating sequence for trellis. The overhead is more for schemes having integer modulation indexes..

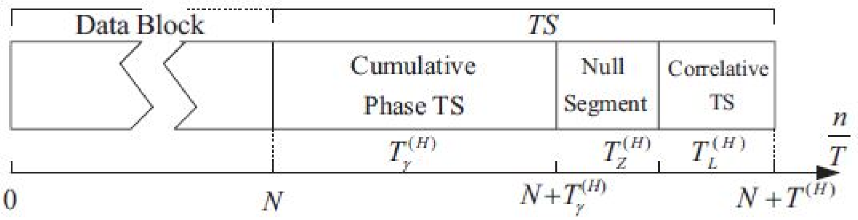


Figure 2.7: Structure of terminated block with different segments of the Terminating Sequence (TS)

2.3 Equalization and Recovery Techniques

In [26] the Authors make utilization of Constant Modulus Algorithm (CMA) for the recovery of SOQPSK transmitted in aeronautical space utilizing iNet information packet structure. The iNET information data packets has known bits which is called preamble and Asynchronous marker (ASM) bits sent with flimsy every data packet. The preamble can be then used to figure in a manner that zero-forcing (ZF) and Minimum Mean Square Error (MMSE) can be calculated. Authors demonstrate that their technique perform well when processed utilizing MMSE and ZF for SOQPSK the general execution is near to the middle taps. At last their work presume that CMA outflanks the channels, CMA equalizers effectively even out the information bits. Furthermore, by utilizing less number of cycle than the inside taps which introduced (i.e. 50 contrasted with 200), These equalizers are indicated to beat the inside tap introduced CMA at higher SNRs, while giving an execution addition of around 1 dB to 3 dB over the altered MMSE or ZF equalizer alone.

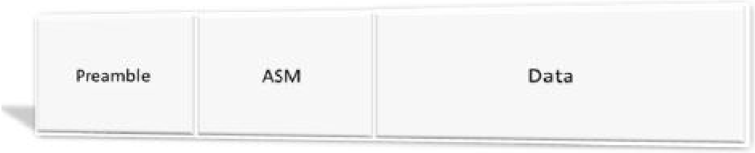


Figure 2.8: iNET Packet Structure

In [27] the authors have proposed symbol timing recovery system for SOQPSK. The proposed timing recuperation system makes utilization of a late CPM elucidation of SOQPSK, where SOQPSK is viewed as being the part of CPM with a compelled (associated) ternary information letter set. A timing error detector (TED) is inferred that is an augmented rendition of a blind TED for CPM, where the proposed expansions consider the information connection of SOQPSK unequivocally. The benefits of the altered TED are exhibited by contrasting its execution and without considering the information connection. Authors demonstrate that a quantization plan can be utilized to yield in optimal performance with avoidable losses. Numerical results given using one of the CPM standard SOQPSK-MIL. Results show that this scheme can be promising for wide range of communication systems because of the fact that has of its low multifaceted nature, its absence of false bolt focuses, and its visually impaired nature; such applications incorporate timing recuperation in non-reasonable recognition plans and false bolt indicators. Moreover, Authors have indicated how a current non-information supported (blind) TED for CPM can be stretched out to the situation where the information images are corresponded and creators have connected this system to SOQPSK. The proposed TED is determined utilizing maximum likelihood principles and a definitely simplified (quantized) adaptation was additionally given. In addition, information relationship can be disregarded when developing the TED; on the other hand, the best results are achieved when the data correlation is considered. The S-bend of the TED is given, which discounted the presence of false bolt focuses. Regardless of its expected high timing lapse change, measured in respect to the MCRB, the bit blunder execution of a MIL-STD SOQPSK locator with the proposed timing recuperation plan shows to be in 0.05 dB of ideal at a sensible circle transfer speed. Because of its effortlessness, its visually impaired nature, and the unlucky deficiency of false bolt focuses, the proposed plan has potential in an extensive variety of uses and is an alluring answer for this profoundly energetic issue..

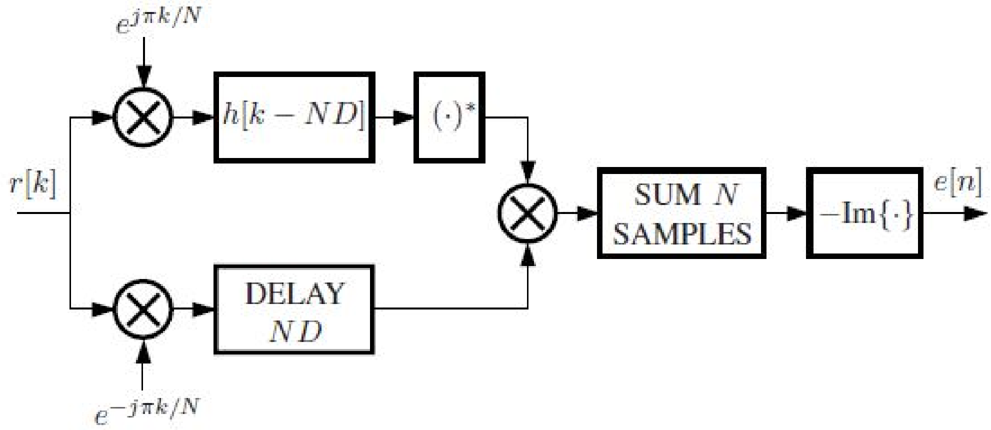


Figure 2.9: Block Diagram of TED

Chapter 3

TRELLIS TERMINATION AND CYCLIC SIGNAL BLOCK

In this chapter we will discuss in depth our working methodology. The SOQPSK modulator is one of the main building block for the generation of signal. The modulator can be seen into two parts precoder and CPM modulator. The procoder of SOQPSK is discussed in detail in the following section.

3.1 SOPQSK Precoder

The basic characteristic that makes SOQPSK different from CPM is ternary data, which is output of the precoder. Fig 1.6 shows the precoder converting binary input into ternary data as an output. Precoder basically has two different parts. Input is oriented as binary and output is always ternary. SOQPSK is viewed as time varying 4-state trellis aligned as n-even and n-odd shown in Fig 3.1. The trellis of SOQPSK is said to be the true orientation of states when given an input. The state variables are arranged as (a_{n-2}, a_{n-1}) n-even and (a_{n-1}, a_{n-2}) for n-odd. Trellis has branches which has its own input and outputs. When an input is given to the precoder the basic role of CPM modulator is orient phase as the standard of SOQPSK which is dictated in (2). The inphase bit of the trellis is said to be the most significant and quadrature is least significant which is already stated in [1].

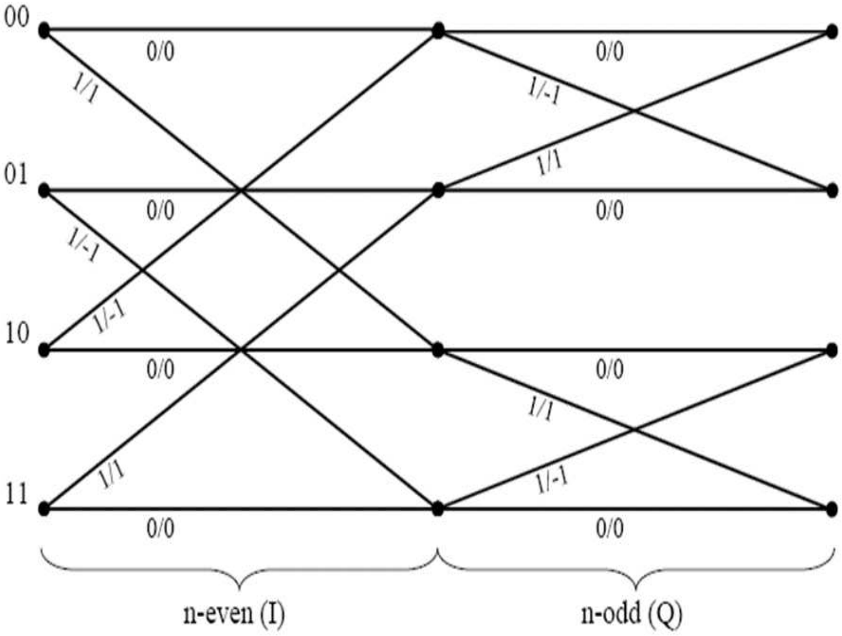


Figure 3.1: 4-state time varying trellis for SOQPSK

The mapping from binary to ternary used in has three strict constraints imposed in [14]

1. x_n is drawn from one of two binary alphabets $0, 1$ or $1, 0$.

2. When x_n=0, the binary alphabet for (x_{n+1}) changes from the one already used for x_n; when x_n is not equal to 0 where (x_{n+1}) does not change.

3. A value of x_n=1 cannot be followed by (x_{n+1})=-1 and vice versa.

The states of SOQPSK are Sn: $(\mathsf{00}, \mathsf{01}, \mathsf{10}, \mathsf{11})$ are divided into n-even and n-odd sections of 4-state time varying trellis. When an input is given to precoder it decides the state and path to be followed. Trellis state indexes $(\mathsf{00}, \mathsf{01}, \mathsf{10}, \mathsf{11})$ and phase state $(\mathsf{0}, \mathsf{1}, \mathsf{2}, \mathsf{3})$ have a one to one mapping. A constellation diagram in Fig 3.2 shows the mapping between trellis state and phase state (CPM modulator state).

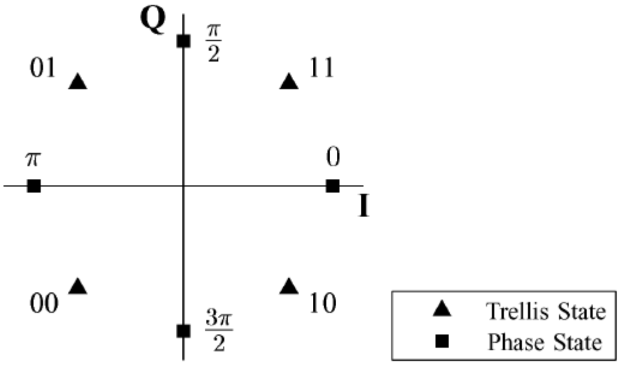


Figure 3.2: Constellation Diagram of SOQPSK

3.2 Cyclic Block Construction

We consider a block-based transmission system with the block length N_T chosen such that the channel remains invariant for the l-th block. To use the efficient Fast Fourier transform (FFT) algorithms in the FDE at the receiver, the linear convolution is constrained to be equivalent to the circular convolution. The length of cyclic prefix N_P has to be greater than the combined memory of the channel and the modulator. The equality of linear and circular convolution is achieved by imposing the following cyclic constraint on the transmitted signal corresponding to the l-th block, i.e.,

$$s(t, \mathbf{x}) = s(t + NT, \mathbf{x}), \forall t \in [lN_T T, (lN_T + N_P)T], \tag{3.1}$$

where N and N_P are the FFT-length and cyclic-prefix length, respectively. The FFT-length N is assumed to be an even number. The total length of the block is $N_T := N + N_P$ symbols.

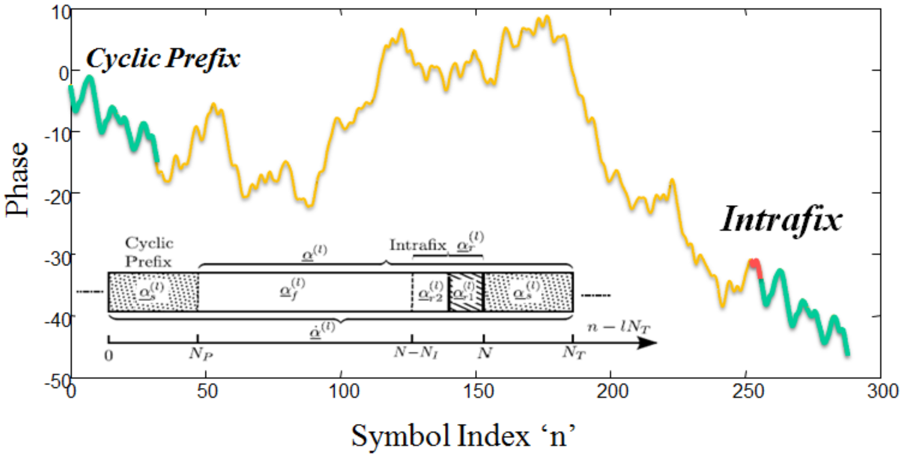


Figure 3.3: Cyclic Signal Block for SOQPSK

The cyclic constraint in (3.1) can be satisfied by following the procedure below. The various steps in the process are also depicted in Fig. 3.4: For each block, choose $N - N_I$ binary source symbols $\alpha^{(l)} := (\alpha_0^l, \alpha_1^l, ..., \alpha_{N-N_I-1}^l)$, where l is the block index and $\alpha_n^l := \alpha_{(l-1)(N-N_I)+n}$. Here N is an even number and N_I is the length of the intrafix bock. A similar notation is used for the input, state vector, and its components, e.g., $a_n^{(l)} := a_{(l-1)(N_T)+n}$, $\chi_n^{(l)} := \chi_{(l-1)(N_T)+n}$ and $P_{n-L}^{(l)} := P_{(l-1)(N_T)+n-L}$. To satisfy the above cyclic condition (3.1), we can equivalently impose that both the the input and the state of the modulator be same during the duration of the cyclic prefix, i.e.,

$$a_n^{(l)} = a_{n+N}^{(l)}, \forall n \in [0, 1, ..., N_P], \tag{3.2}$$

and

$$\chi_{N_T}^{(l-1)} = \chi_{N}^{(l)}. \tag{3.3}$$

Construct the intermediate N-length block as follows:

$$\mathbf{a}^{(l)} := \left[\alpha_s^{(l)}; \alpha_f^{(l)}; \alpha_r^{(l)}; \alpha_s^{(l)}\right],$$

where $\alpha_f^{(l)} := \left[\alpha_0^{(l)}, \ldots, \alpha_{N-N_P-N_I-1}^{(l)}\right]^T$, and $\alpha_s^{(l)} := \left[\alpha_{N-N_P-N_I}^{(l)}, \ldots, \alpha_{N-N_I-1}^{(l)}\right]^T$. The intrafix segment $\alpha_r^{(l)}$ itself can be further divided into two sub-segments such that $\alpha_{r1}^{(l)} := [\alpha_{N-N_I-L+1}^{(l-1)}, \ldots, \alpha_{N-N_I-1}^{(l-1)}]^T$, and now $\alpha_{r2}^{(l)}$ consisting of two binary symbols c_1 and c_2 is selected such that

$$\left(P_{n-N_I-L}^{(l)} + \sum(p(\alpha^{(l)_n})) + p(c_1) + p(c_2)\right)_4 = P, \tag{3.4}$$

is satisfied. The intrafix for l-th block is now defined as $\mathbf{x}_r^{(l)} := \left[\mathbf{x}_{r2}^{(l)}; \mathbf{x}_{r1}^{(l)}\right]$. Finally, the N_T-length cyclic block is composed as follows:

$$\begin{aligned}\dot{\mathbf{x}}^{(l)} &:= \left[\mathbf{x}_s^{(l)}; \mathbf{x}^{(l)}\right], \\ &= \left[\mathbf{x}_s^{(l)}; \mathbf{x}_f^{(l)}; \mathbf{x}_{r2}^{(l)}; \mathbf{x}_{r1}^{(l)}; \mathbf{x}_s^{(l)}\right].\end{aligned}$$

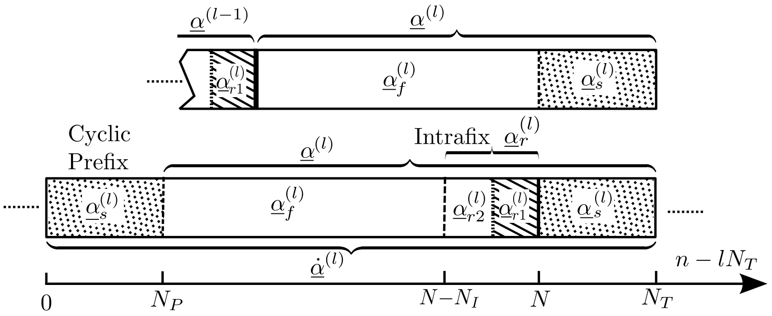


Figure 3.4: System block diagram of a cyclic single-h CPM transmitter.

The resulting signal $s(t, \mathbf{x})$ satisfies the cyclic constraint in (3.1). These steps are also shown in the transmitter block diagram of fig. 1.6. Double-lined connections between the blocks represent a vector. The label of the vector is mentioned on the top of the connection and its dimension is specified on the bottom. The process of cyclic prefix insertion is expressed in terms of the matrix $\mathbf{T}_{CP}$ defined in fig 3.3. The blocks labeled S/P and P/S denote serial-to-parallel and parallel-to-serial converters, respectively.

3.3 Trellis Termination for Cyclic Prefix Insertion

In this research we address the problem of trellis termination of SOQPSK along with Cyclic Signal Block generation. The CPM modulator has correlative states which are 128 and Precoder has 4 states. The total number states of SOQPSK trellis are 512 [16]. The higher number of states of SOQPSK subjects to fairly complex termination. The one to one mapping of phase state and trellis translates that if we control the input we can minimize the complexity at transmitter. The motivation for the generation of Cyclic signal block is; to regain the initial state of transmitter by efficiently terminating the trellis. The number of symbols required to terminate trellis exactly are 9. We show that in later example how the number of symbols affect the trellis. The increased number is not a good choice as it doesn't provide good termination with optimal cost.

The cyclic signal shown in Fig.3.3 shows that data block consists of two data blocks A and B. A was first data block transmitted, then block B is transmitted, we want to regain the state A after the transmission of block B. At the end of block B transfer a pattern of terminating sequences bits are added to terminate in a such a way that initial state of the transmitter is regained. The initial state of the transmitter depends on the correlative part of transmitted block, the number of bits that are in control are (Even/Odd)

2 which is the input of precoder. The cyclic behavior does not depend on only one characteristic of the transmitter. The basic idea and requirement for the cyclic signal is to regain the same state, In order to do that cyclic properties needs to be satisfied. The input bits (correlative part) has 7 bits as in original transmitted block needs to be the same as transmitted in block A. The transmitter can only control the input bits (E/O). These input bits are precoder out c1 and c2 Alpha in the correlative part. On the basis of input (E/O) along with the bits present in the correlative part leads to same phase as original yielding to required block. The number of symbols used for this efficient termination are studied in this research. Trellis is not effected by the symbols used to terminate and insert cyclic signal. SOQPSK trellis complexity can be minimized by removing redundant sequences and completing each those sequences which generate same output regardless of state. The states of Precoder S_n: $(00, 01, 10, 11)$ doesn't cater the number of repeating sequences. It is very useful contribution we have studied that if we compliment the number of repeating sequences in such a way we don't need to make the precoder state same as it was in initially transmitted block. The part should be in favor so that the precoder input is already in control to make the same phase, resulting in same state. The generic equation for binary to ternary used in [16] can be modified as if we compliment the redundant sequences which are generating same output.

If the states S_o and S_1 are same taken from S_n

$$x_n = (f(S, a_n) =(f(\hat{S}, \hat{a}_n)). \tag{3.5}$$

$$(-1)^{n+1}\left(2\hat{(}a_n - 1\right)(\hat{a}_n - \hat{a}_{n-2}) \tag{3.6}$$

$$(-1)^{n+1}(2(a_n - 1)(-1)(a_n - a_{n-2}) \tag{3.7}$$

$$(-1)^{n+1}(2(a_n - 1)(a_n - a_{n-2}) = x_n \tag{3.8}$$

The complementary sequences doesn't affect the states of SOQPSK precoder (7) (8) . Thus, resulting in minimal trellis states which yields in less complexity both at transmitter and receiver. Trellis stays in one of the 4 states at each given input. [16] The states of the precoder can be complemented if the sequences are producing same output, this is an efficient way of seeing trellis of SOQPSK. The aim of this technique is to ensure the trellis is terminated efficiently. Less number of trellis states yields into less number of symbols for termination and cyclic signal block generation. The trellis termination for the case of SOQPSK MIL is exact [16] while SOQPSK TG has only approximation for this purpose.

3.4 Trellis Termination Techniques

3.4.1 Exact Trellis Termination

This method is basically traversing through each state when an input is given to the SOQPSK precoder, it works like brute force. Each state has to be addressed until a trellis can be terminated, the number of symbols required to terminate may reach to 9. SOQPSK trellis can be seen as finite state machine. When an input is given, each state checks for the output and follows branch-trees through that transition. Every time precoder is given an input the state traverses from even to odd in time varying trellis. This behavior is well discussed in [22], [16]. SOQPSK time varying trellis is complex in this case more specifically for TG, needs more symbols to completely terminate the trellis. But, for the case of SOQPSK-MIL it is the exact representation. We see an example if the input is given how does states are switched from n-even to n-odd and how does that effect the overall termination when doing this in a simple manner. If the precoder is given an input from the set of binary $0, 1$ or $1, 0$, We have seen that precoder is always in one of following states S_n = (00,01,10,11) [16] [28]. The number of symbols that are required for termination trellis exactly are 9 at-most. While it takes only 4 symbols to terminate the trellis for SOQPSK-MIL. The trellis for both variants is same, since SOQPSK-MIL is exact representation while SOQPSK-TG has approximation due to the inherent memory introduced in it. The simpler method is exhaustive it terminates each state, hence consuming more symbols. The increased number of symbols used in intra-fix part for the termination wastes the bandwidth of the channel and makes transmitter complex. The termination for SOQPSK-TG is sequential with CPM modulator following Correlative states and Precoder. SOQPSK-TG which has inherent memory and partial response property. The states of precoder, correlative phase and CPM modulator has to be addressed for exact termination. The SOQPSK signal block structure in . shows that the signal transmitted without any constraint has 69984 states. These states are defined as follows. The transmitted SOQPSK signal looks like

$(Even/Odd)$×(Precoder States)×(Correlative Phase)×(CPM Phase)

$(E/O,\ S_q,\ \alpha_n,\ P_l)$

The equation yields in $2 \times 4 \times 3^7 \times 4 = 69984$. The Correlative part of the signal has lot of redundancy. This repetition is removed through the three constraints which is well discussed in [7] [9]. These constraints minimizes the states from 69984 to 512. The distribution when expanded leads to unique states which are the part of SOQPSK signal. The factor 3^7 is minimized to 2^7. The SOQPSK-TG has more states as compared to limited SOQPSK-MIL having 16 states with the termination using 4 symbols at-most.

The exact trellis termination reduces (1 or 2) symbols in overall termination. SOQPSK-MIL trellis termination for the same trellis can be used by brute force/exact termination as the number of states are limited. While SOQPSK-TG has increased number of states due to inherent memory and partial response characteristic. The Exact termination is the only choice here to terminate the cyclic signal of SOQPSK-TG. The Exact termination costs 9 symbols at most for termination the trellis exactly. The termination of trellis is sequential terminating CPM phase, following Correlative symbols. The termination is dependent on the choice of Precoder input.

3.4.2 Approximate termination using Laurent Decomposition

The third technique for the SOQPSK termination is Approximation using Laurent decomposition. It has been studied in [29], [16] the role of approximation can reduces the number of signal pulses which minimizes the mean-square error for an arbitrary set of modulation indexes. The basic objective of using Laurent decomposition is to reduce the number of pulses for the proposed modulation index, resulting in a good approximation. The approximation technique has been well studied in [15]. The Approximation has been significant for any constant amplitude binary phase modulation which can also be expressed as a sum of a finite number of time limited amplitude modulated pulses (AMP decomposition). Pulses which are of significant energy can be written as single pulse canceling the effect of low energy pulses. Single-h CPM signal can be expressed as a superposition of partial response amplitude modulated pulses. Fig 3.5 shows the Laurent signal for Single-h SOQPSK.

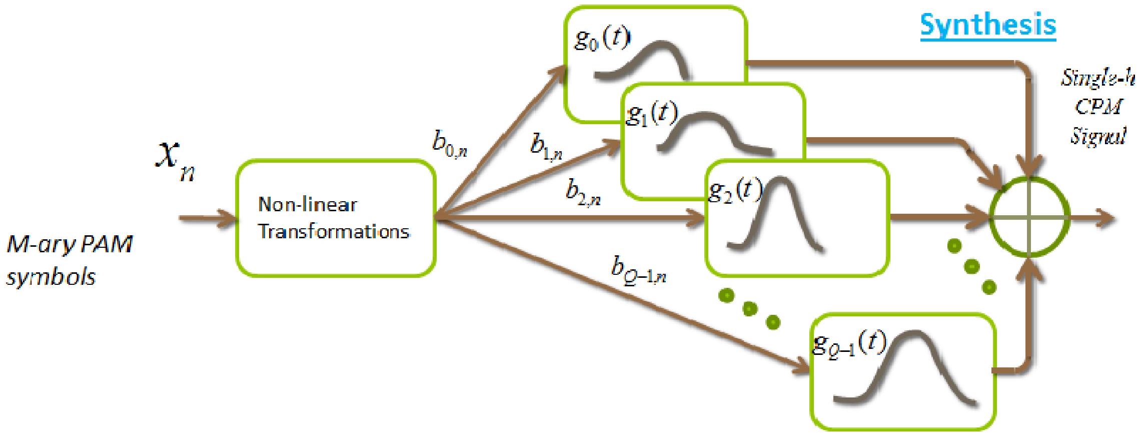


Figure 3.5: Laurent signal for SOQPSK

SOQPSK-TG has 4374 pulses which are generated from 49152 pseudo symbols, the exact representation does not exist furthermore, it is complex for SOQPSK-TG [30]. The background knowledge of this conversion has been given in [22], [16]. The energy of several pulses have no impact in overall distribution, most of the pulses remain closer to zero, negative or have least energy. We have taken into account the significant pulses having high energy by complementing the redundant sequences which is well explained in Section 3.3. The following figure shows the number of 4374 pulses generated from 49152 pseudo symbols.

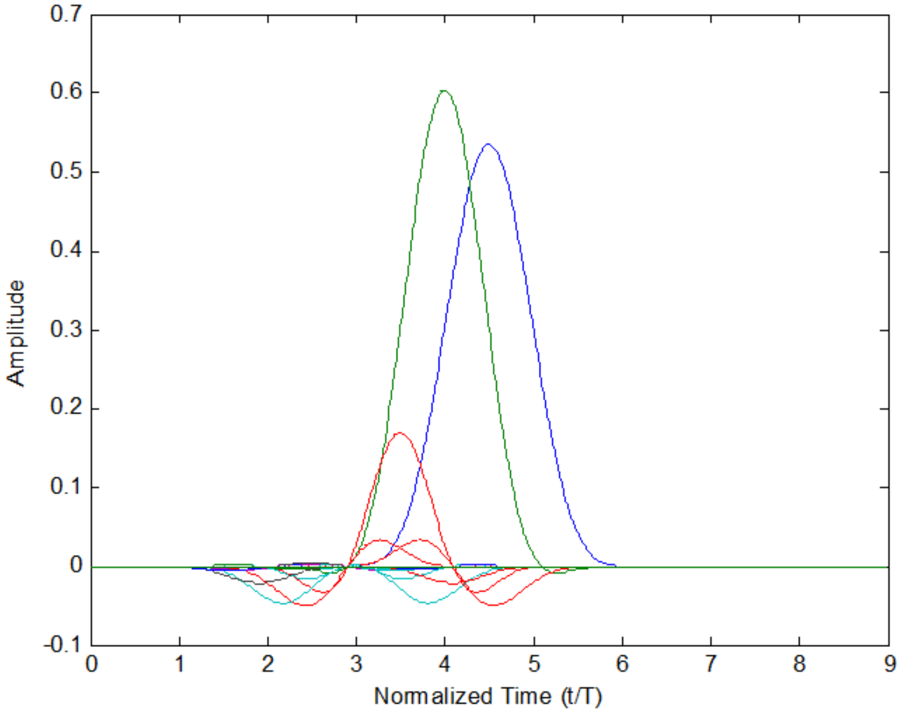


Figure 3.6: Total number of Laurent pulses (4374)

Chapter 4

RESULTS AND DISCUSSION

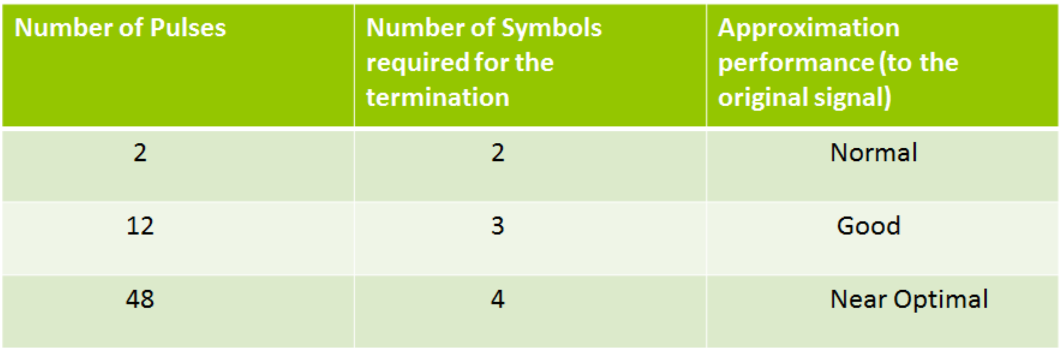
This chapter presents detailed results along with relevant discussions. In this chapter, Section 4.1 explains the exact termination for SOQPSK that takes 9 symbols. The trade off of between pulses and the no of symbols required for the termination is shown in Section 4.2. Power spectral density of SOQPSK-TG when different number of Laurent pulses are used for reconstruction of the waveform in the prefix part of the transmitted block is shown section 4.3.

4.1 Exact Trellis termination

This section presents the results of termination of trellis for SOQPSK-TG when the cyclic behavior is ensured. The number of symbols required for the termination is 9 at-most. The Precoder has the state information when an input is received. The state memory already in correlative part has to be pushed in such a way that the new incoming input terminates the trellis and the desired state of the transmitter is achieved.

4.2 Approximate Technique using Laurent Decomposition

In this section, we show the results of our research work. We have discussed Laurent decomposition in depth in section 3.4.3. The trade-offs trends are shown in this section between the number of pulses and symbols used for the approximation. The approximate technique is one good measure of understanding CPM modulator and the properties of constant envelope. When the the number of pulses are increased it leads to better constellation in the In-phase and the Quadrature part but the number of symbols required in intra-fix part for the termination increases. We show in the following table how actually does effects the trellis, and overall signal efficiency when we increase and decrease number the number of pulses for the approximation. The basic idea here is if we increase the number of pulses for the approximation its costs more symbols for the termination, resulting in very good approximation (closer to original signal). The Laurent decomposition gives the freedom to choose between different number of available pulses (2-4374).



Number of Pulses	Number of Symbols required for the termination	Approximation performance (to the original signal)
2	2	Normal
12	3	Good
48	4	Near Optimal

Figure 4.1: Laurent Decomposition Trade-offs

Fig 4.1 shows the trade-offs between number of pulses used for approximation and the number of symbols used for the termination (intra-fix) length. When we consider 2 pulses for the approximation, the number of symbols required in intra-fix part costs 2 symbols. The resulting signal of this approximation gives satisfactory approximate signal, the properties of constant signal deteriorates gracefully if the number of pulses used are less. The performance of 12-pulse approximation costs 3 symbols in intra-fix part resulting in good approximate signal. 48-pulse approximation leads to 4 intra-fix symbols for the termination but the resulting signal is near optimal (same as original). The larger number of pulses taken into account have strong impact in overall signal properties, i.e,. (C.E, PSD, MMSE). The more pulses are taken into account the better overall signal properties are satisfied.

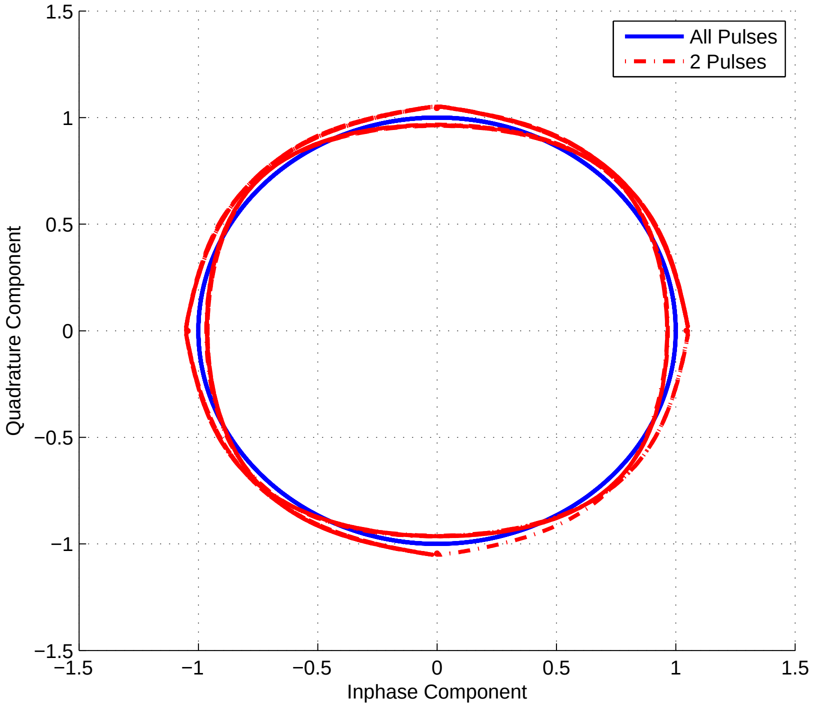


Figure 4.2: SOQPSK All pulses versus 2 pulses Approximation

Fig 4.2 shows the results of approximation. X-axis shows the Inphase Component and the Y-axis shows the Quadrature Component of SOQPSK. The total number of Laurent pulses (4374) pulses are mapped in thick blue and 2 pulses approximation mapped in dotted red. The 2-pulse approximate technique performs just satisfactory in this case the signal properties like Continuous phase and Power Spectral Density are effected. The roundness of the 2-pulses approximation overlaps the original signal, the signal properties for this approximation deteriorates gradually. Using minimum number of pulses for the approximation results in wavering signal.

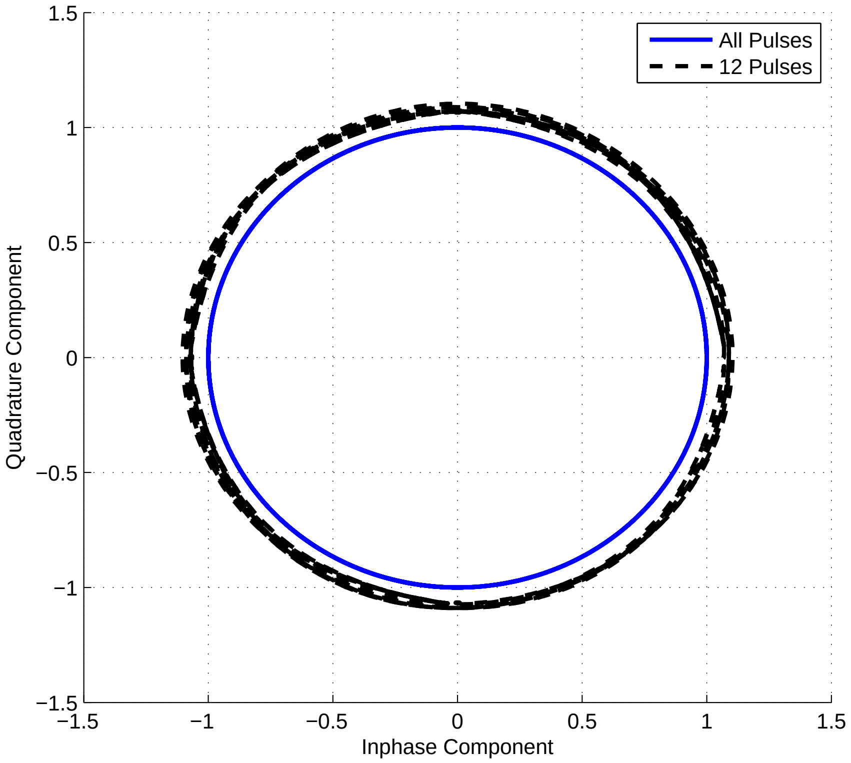


Figure 4.3: SOQPSK All pulses versus 12 pulses Approximation

Fig 4.3 shows the results of approximation. X-axis shows the Inphase

Component and Y-axis shows the Quadrature Component of SOQPSK. The total number of Laurent pulses are 4374 and approximate pulses taken into account are 12. Laurent pulses 4374 are shown in thick blue and 12 pulses in doted black. The approximate result of 12 pulses show good overall signal performance taken into the considerations constant signal properties for SOQPSK. The generated signal here shows that the roundness of the 12 pulse approximate technique is good, the properties such as (PSD, Contant Envelope and MMSE)nees to be taken into account when satisfying signal continuous signal properties.

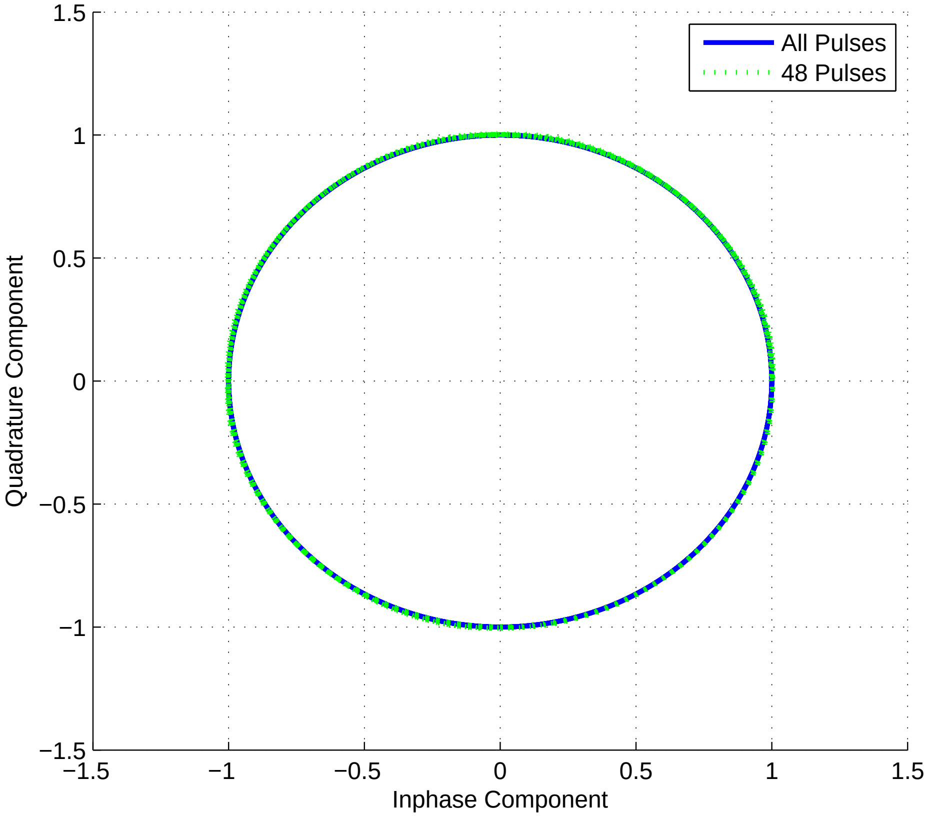


Figure 4.4: SOQPSK All pulses versus 48 pulses Approximation

In Fig 4.4 the approximation of original signal (4374 pulses) versus 48 pulses has been shown. X-axis shows the Inphase Component and Y-axis shows the Quadrature Component of SOQPSK. Laurent pulses 4374 are shown in thick blue and approximate technique using 48 pulses are shown in dotted green. The pulses are almost mapped on each other, the performance is said to be near optimal in this case. The desirable properties of the signal such as (PSD, Constant Envelope, MMSE) are taken into account for better evaluation of the generated signal. We see the approximate technique tend to perform closer to the original signal (optimal performance).

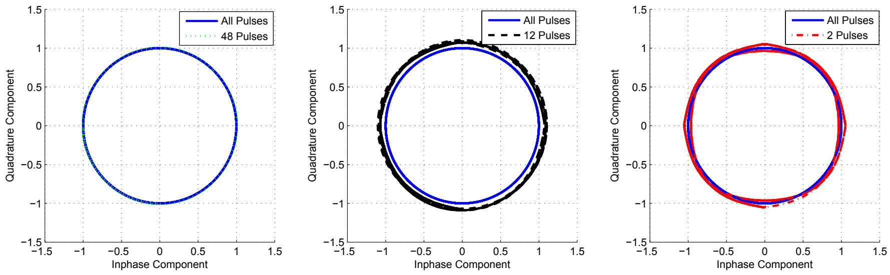


Figure 4.5: SOQPSK All pulses Approximation

In Fig 4.5 the approximation is shown, the total no of pulse 4374 along with 2,12 and 48 pulses is mapped on constellation diagram. X-axis shows the Inphase Component and Y-axis shows the Quadrature Component of SOQPSK, To have an idea the more round signal having eccentricity zero is supported in our case of observation. We have seen when we increase the number of pulses we get better approximation (desirable signal), though the number of symbol for termination may increase. If we take more pulses the chance of getting closer to the original signal increases. So, the increased number of symbols does not matter until the approximate results are well enough to rely on.

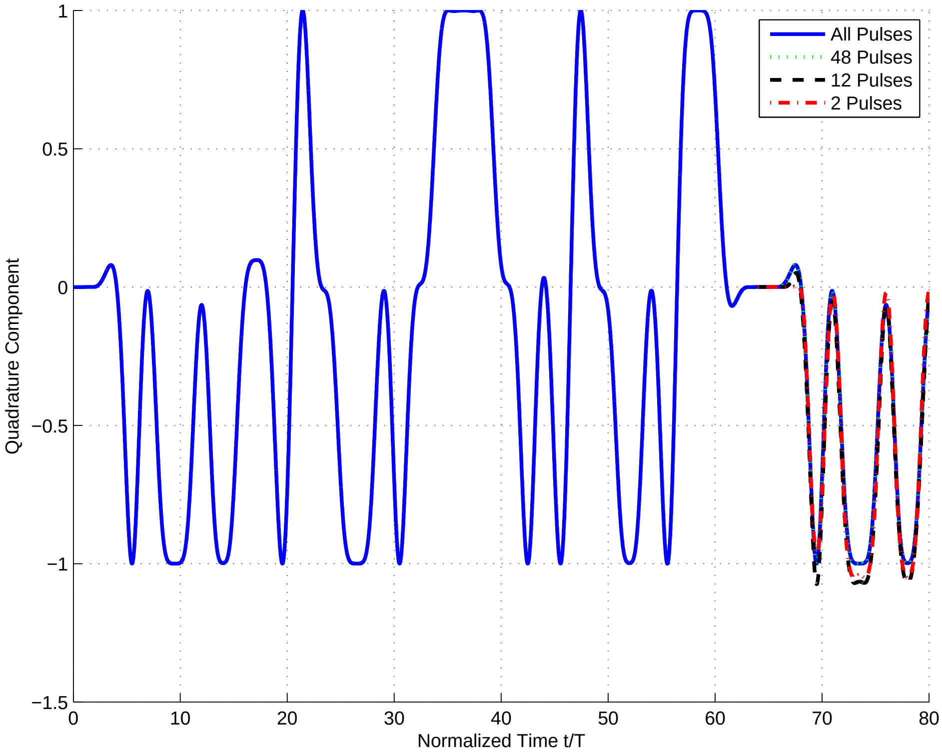


Figure 4.6: SOQPSK Quadrature Component for SOQPSK using cyclic block

The Quadrature Component for SOQPSK is shown in Fig 4.6. X-axis shows Quadrature component and Y-axis shows Normalized Time. In the start of quadrature component an initial block is transmitted, we see the same block at the end of transmission after transmitting intermediate block. The same block at the start and at the end of the transmission is cyclic signal block. We have generated same cyclic signal block using different approximate techniques. When we increase the number of pulses for the cyclic block construction to replicate the same block again (cyclic block), the signal gets closer to the original Laurent signal. The increased umber of pulses yields in optimal performance.

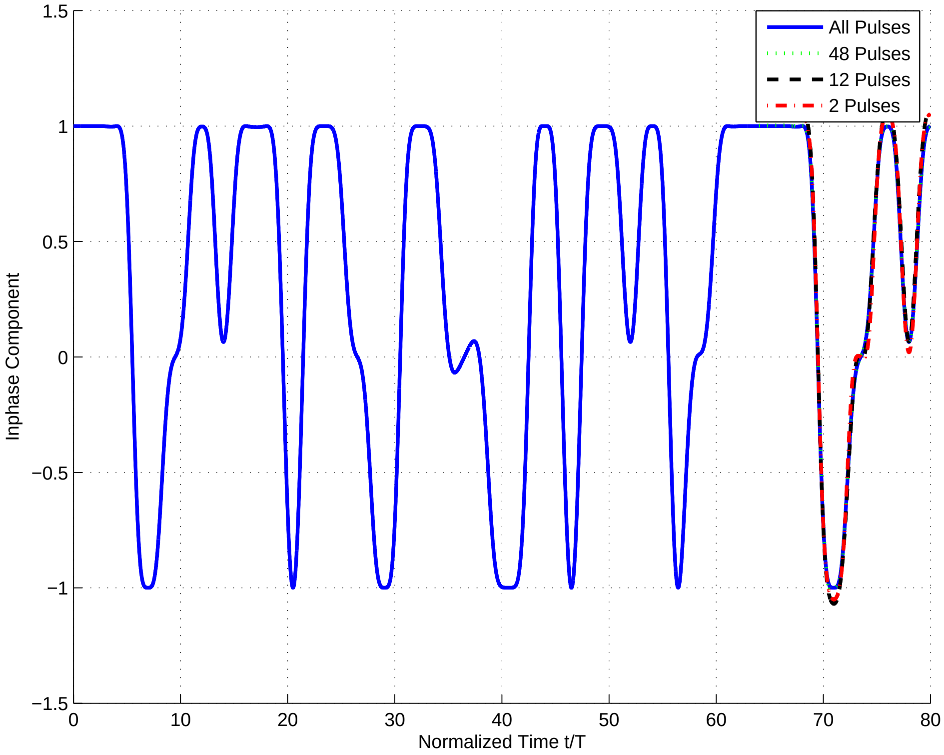


Figure 4.7: SOQPSK Inhpase Component for SOQPSK using cyclic block

The Inphase Component for SOQPSK is shown in Fig 4.7. X-axis shows Quadrature component and Y-axis shows Normalized Time. In the start of quadrature component an initial block is transmitted, we see the same block at the end of transmission after transmitting intermediate block. The same block at the start and at the end of the transmission is cyclic signal block. We have generated same cyclic signal block using different approximate techniques. When we increase the number of pulses for the cyclic block construction to replicate the same block again (cyclic block), the signal gets closer to the original Laurent signal. The increased umber of pulses yields in optimal performance.

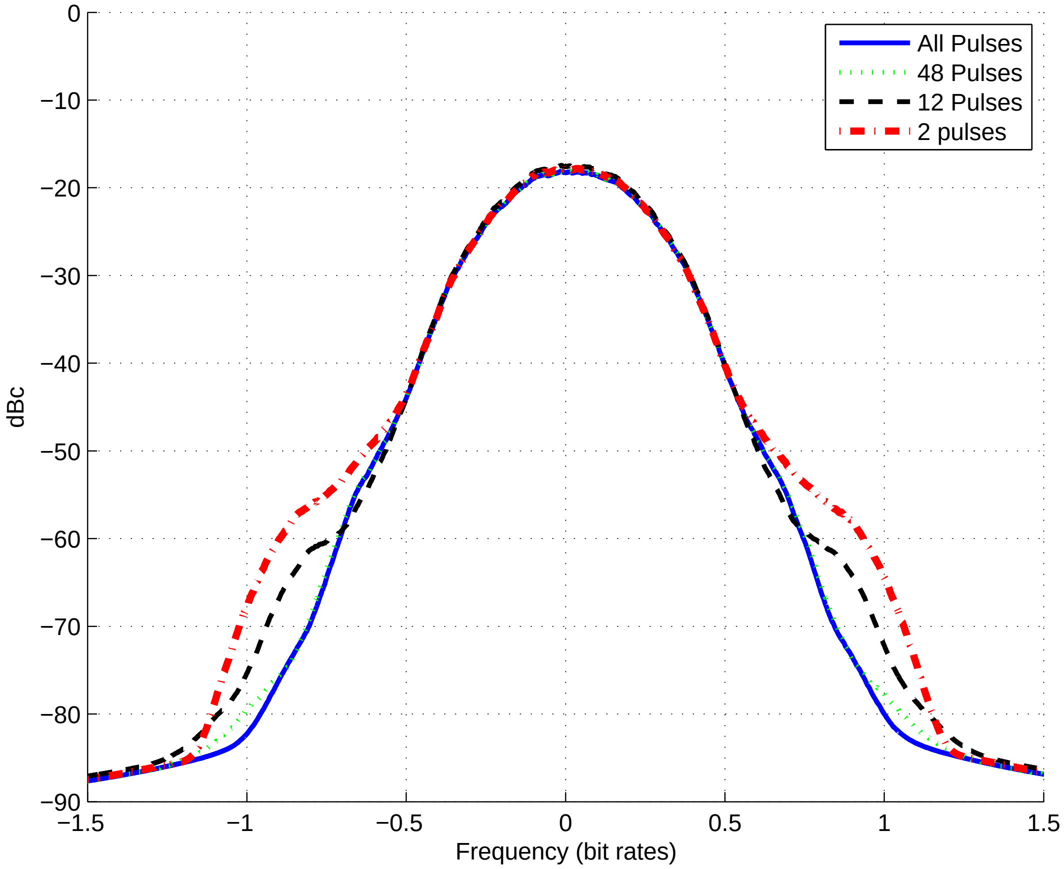


Figure 4.8: Power Spectral Density of SOQPSK

In Fig 4.8 the power spectral density of SOQPSK is shown, the X-axis shows the frequency (bit rates) and Y-axis shows the decibels relative to the carrier (dBc). We see that Laurent pulses 4374 pulses are mapped using blue line following green, black and red line. The green line shows the approximation using 48 pulses, black line shows using 12 pulses and red line shows 2 pulses. The figure the actual signal is labeled in blue line, closer to blue is green line (48 pulses) the Psd of Blue (original approximation) and green (48 pulses) is very close as compared to other pulses. The better PSD property sates that signal should be compact and the side lobes should be least saturated. We see here the 48-pulse approximate is near optimal to the original signal, the peak and side lobes of signal can be seen. The increased number of pulses gives better spectral efficiency and bandwidth efficient signal.

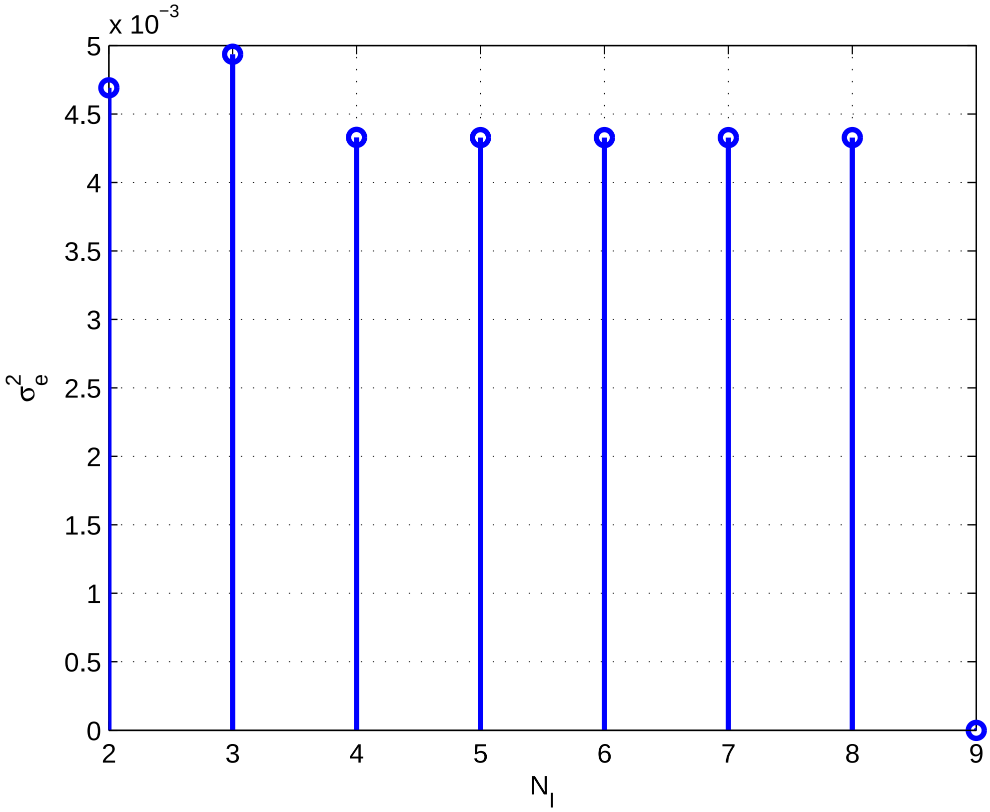


Figure 4.9: SOQPSK Mean Square Error

Fig 4.9 shows the results of MMSE. X-axis shows the number of intrafix symbols and Y-axis shows the Errors. By using Laurent pulses we have taken into account 48 high energy pulses out of 4374 pulses. After 48 pulses the energy of several pulses get significantly low while most of the pulses remain closer to negative. When we use (2-pulses) for approximation its costs 2-symbols for the termination, the erros in this case are normal. Using (12-pulses) for approximation its costs 3-symbols for the termination, MMSE increases. The reason of increased MMSE is the effect of negative energy pulses that contribute into high MMSE generation. Moreover, A very interesting study is when we increase the number of symbols upto 9 for the termination and pulses upto 4374, the MMSE reaches to zero. The increased number of pulses when taken into account leads to MMSE closer to zero, which is an exact termination.

Chapter 5

CONCLUSION AND FUTURE WORK

5.1 Conclusion

A novel technique is proposed for cyclic signal generation of SOQPSK-TG that enables FDE at the receiver. It has been found that 9 symbols are required for exact cyclic signal generation. The approximate technique gives the freedom to choose from (2 - 4374) pulses with intra-fix length (2 - 9) symbols. The more the pulses for approximation, the more symbols required for the termination yielding better signal representation. As the number of intra-fix symbols are reduced (from 9 to 2), the desirable properties of the signal (such as C.E., PSD, and MSE) deteriorate very gracefully.

5.2 Future Work

Our future work is directed towards designing an optimal Matched Filter receiver for SOQPSK-TG. The basic motivation behind the idea is to cater the transmitted block resulting minimal complexity at the receiver. We plan to establish a technique that the cyclic behavior that we have gained at the transmitter can be used in such a way that the receiver can easily distinguish between next state, previous and the regained state with the minimal complexity. We also plan to work on the receiver design, making it according to the desired output of the transmitter.

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