A COMPARATIVE STUDY ON SYNCHRONIZATION ALGORITHMS FOR VARIOUS MODULATION TECHNIQUES IN GSM

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ABSTRACT

The study on various modulation techniques implemented in GSM is the main area of interest to address the problem of estimating synchronization parameters. On estimation of synchronization parameters, a robust synchronization algorithm can be developed for GSM standards. Later in this paper a fast synchronization algorithm for Gaussian Minimum Shift Keying (GMSK) modulation technique is proposed for GSM in mobile devices. GMSK is the spectrally efficient modulation technique with constant envelope property. This synchronization algorithm for GMSK results in low complexity and low signal-to-noise ratio (SNR) for GSM standards. Symbol-by-symbol (SBS) demodulator is used for demodulating GMSK in GSM which can outperform the traditionally high complexity Viterbi Algorithm, but SBS assumes perfect synchronization in designing the demodulator. The proposed method will extend to practical scenario by considering imperfect synchronization caused by synchronization algorithms at the receiver.

Index Terms: CPM, GMSK, GSM, SNR, Synchronization Parameters

I. INTRODUCTION

GSM is a standard developed to describe protocols for second generation (2G) digital cellular networks used by mobile phones. GSM being operated in more than 219 countries and territories, became default global standard for mobile communications as of 2014 amidst more than 90% market share. [1]. Designing any service for mobile devices using GSM is moderately complex due to its limited resources availability like small battery capacity, limited input/output capabilities and also weak radio transmitters. GSM architecture can be divided into three groups – mobile station (MS), base station subsystem (BSS), and network subsystem.
Physical layer in GSM is responsible for the modulation of signals. The main goal of modulation is to process the periodic waveform (the data to be transported) by varying certain parameters in order to use that signal to convey the message with the best possible quality while occupying the least of radio spectrum. GMSK is a form of continuous-phase FSK (Frequency Shift Keying) in which the phase change is changed between symbols to provide a constant envelope. Despite the attractive features of CPM, the complexity at receiver is high due to the implicit memory of modulation, and it requires maximum likelihood sequence detection (MLSD) for the best performance \[2\]. Compared with other modulation techniques for GSM, GMSK showed high spectral efficiency than QPSK, BPSK, 8-PSK, 16-PSK, MSK \[2\]. In the GMSK, the side lobe levels of spectrum are reduced by passing the modulation data waveform through a pre-modulation Gaussian pulse shaping filter \[2\].

In any networking systems, modulation techniques are quintessential for system to be in synchronization. In the GSM systems, BCCH (Broadcast Control Channel) carriers provide the necessary information for synchronization. Synchronization in GSM occurs in time division multiple access (TDMA) and frequency division multiple access (FDMA). Synchronization is a multi-parameter estimation problem. The multi-parameters are symbol timing offset (STO), carrier frequency offset (CFO), and carrier phase offset (CPO). Considering the limited resource availability and burst transmission characteristics in GSM, fast synchronization algorithms with low complexity are necessary \[3\].

II. LITERATURE REVIEW

In \[4\] Morelli and D’Amico, proposed a joint maximum likelihood (ML) estimator for synchronization parameters like symbol timing, carrier phase and frequency offset estimation in AWGN channels. Their work operated on alternating BPSK symbols for training sequence which simplifies the likelihood function significantly leading to a rather simple estimation algorithm. From the work presented in \[4\], we can conclude that the training sequence not only affects the estimation performance but it may also affect the complexity of the estimation algorithm.

From the work presented by Zhao et al. \[5\], they have presented an efficient phase and timing synchronization algorithm which can be applied to all continuous phase modulation techniques in communications. Despite its good performance in fading channels, the complexity of the algorithm is high in computation and prior to synchronization frequency ambiguity has to be resolved.

With respect to the paper presented by Gunther and Moon in \[6\], they have proposed synchronization algorithm for burst-mode QPSK signals, which includes frame synchronization in addition to timing offset, frequency offset and phase offset. The algorithm presented in \[6\] is based on kurtosis, which is a statistical measure.

Kurtosis is related to second and fourth order moments of random variable. Bit Error Rate (BER) of frequency estimation in low SNR regions is highlighted in this work. The results obtained from simulation shows that the errors in frequency offset estimation leads to errors in symbol timing and carrier phase estimation thus proportional to the increase in BER. The work carried out in \[7\] by Huber and Liu, proposed that the delay occurred in the transformation of the CPM signal into frequency domain using non-orthogonal function results in phase offset that is predicted using ML algorithm, along with carrier phase. This algorithm works only for timing delays which are smaller than the symbol duration, and hence this \[7\] proposed system can be used in phase locked loop structure encountering with false clocks.

Nezami in his work \[8\], proposed a synchronization method for minimum shift keying modulation technique in communication systems based on Discrete Fourier Transform (DFT) of the received preamble. Even though the alternating training sequence estimates all three synchronization parameters, overall performance in low SNR region is poor.
In [9], Lee et al. has proposed a maximum likelihood algorithm for synchronizing frame bursts of PSK signals in the presence of frequency offsets. Carrier phase and frequency offset are treated as undesired equally distributed parameters in the derivation of likelihood function. In [9], the author mentioned that the work requires known training sequence and hence these are well suited with data-aided (DA) techniques.

The work carried out by Ehsan Hosseini and Erik Perrins in [10], shows that the algorithm which is implemented in feed forward manner estimates the frequency offset via two Fast Fourier Transform (FFT) operations. After the frequency estimation, symbol timing and carrier phase can be computed via closed-form expressions.

A feed forward technique for DA joint symbol timing and frequency estimation algorithm for GMSK signals is proposed by Huang et al. [11]. The performance of GMSK modulation in estimating synchronization parameters depends on the error rate of frequency offset and symbol timing.

III. PROPOSED SYSTEM

Synchronization offers the potential for increase in capacity of cellular networks based on GSM and Enhanced Data rates for GSM Evolution (EDGE). Tight frequency reuse and fractional loading together allows synchronization in the network to be minimized through the intelligent share of frequency hopping parameters. Modulation index of 90° for the traditional GMSK technique is known to have a very narrow power spectrum. For fast and efficient synchronization in GSM mobile devices, both sender and receiver which mean both modulation and demodulation techniques must perform optimally well over radio channel. SNR is calculated to know the efficiency of signal transmission, lower the SNR value higher is the efficiency of the system. Bit error rate (BER), is estimated to know the percentage of error bits that occur while transmitting the data. Lower the percentage of BER, higher is the throughput of the system. Synchronization parameters which are evaluated for robust synchronization method are symbol timing offset (STO), carrier phase offset (CPO), and carrier frequency offset (CFO). Continuous phase modulation technique is used in our work for developing fast synchronization algorithm for GSM communication systems.

CPM technique is implemented for mobile communications because of its power- and bandwidth-efficient signaling scheme. Minimum-shift keying (MSK) and Gaussian MSK (GMSK) have been implemented in variety of applications which are types of binary CPM. M-ary CPM systems which mean CPM with multi-level symbol inputs have higher bandwidth efficiency than binary CPM systems, but due to the complexity in receiver for demodulation and synchronization problems - the use of m-ary CPM systems is restrained [12]. Complexity of a CPM receiver is determined by both demodulator complexity and also the complexity of front-end processor (FEP), which is used to generate sufficient statistics for signal detection and parameter estimation. For m-ary partial response, an optimal coherent CPM demodulator requires a complex maximum likelihood (ML) sequence detector [13]. In our proposed system, symbol-by-symbol (SBS) demodulator which is simpler to implement is carried out as opposed to complex Viterbi algorithm. SBS demodulator assumes perfect synchronization while designing the demodulator. By implementing SBS demodulator with the assumption of perfect synchronization, a robust synchronization algorithm can be developed for GMSK modulation technique by estimating the performance of synchronization parameters with low SNR value and low BER percentage.

IV. RESULTS

In the GSM standard, Gaussian Minimum Shift Keying with a time-bandwidth product of 0.3 was chosen as a compromise between spectral efficiency and inter symbol interference. For different
values of SNR, bit error rate (BER) is computed using MATLAB. Figure 1 shows BER vs. SNR graph for MSK and GMSK modulation schemes. The figure shows us that for higher values of SNR, GMSK is better compared to MSK.

![BER Vs. SNR graph plot of MSK and GMSK](image)

Fig. 1. BER Vs. SNR graph plot of MSK and GMSK

Figure 2 and Figure 3 shown below provide the comparison of symbol timing and carrier frequency offset of other proposed systems [14] [15] [3] [16].

![Timing synchronization of GMSK for different methods](image)

Fig. 2. Timing synchronization of GMSK for different methods.

Once the frequency estimate (CFO) is available, the carrier phase can be computed. The larger value of observation duration of phase synchronization gives us better phase estimation. The CPO estimation plot is shown in Figure 4. During data transmission, CPO will be updated accepting data-decision feedback method.
V. CONCLUSION

Symbol by symbol (SBS) demodulator is implemented for demodulating GMSK signals for developing an efficient synchronization algorithm for GSM standards in mobile devices. Simple SBS demodulation scheme is designed with the assumption of perfect training sequence for synchronization, which provides better results than complex Viterbi Algorithm demodulator in terms of SNR and BER values. The results of joint estimation of synchronization parameters such as CFO, STO and CPO, for the proposed systems prove to be better than previous methods for GSM standards.
REFERENCES

AUTHORS DETAILS

SAMARTH KERUDI has received BE degree in Electronics and Communication Engineering from STJIT, Bangalore, Karnataka, India in 2008 and M.Tech degree in Digital Communication and Networks from UBDT, Davanagere, Karnataka, India in 2010. He has teaching experience of over 5 years. He is currently pursuing PhD degree from Jawaharlal Nehru Technological University, Hyderabad, Telangana India. His main area of interest is digital communication.

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