Optimization of the Viterbi and Viterbi Carrier Phase Error Detection Algorithm

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Abstract-**Following a literature survey, the Viterbi and Viterbi phase error detection (PED) algorithm was chosen for software implementation in all -digital demodulators. For this algorithm it is desired to have very fast acquisition time and also a jitter free tracking. Simulations show that there is a substantial amount of tracking jitter; also acquisition time is not fast. To overcome this problem, the optimizer has been introduced to ensure that the tracking performance is almost jittering free without increasing the error acquisition time. Simulations show that new optimizer is very useful in all kinds of M-PSK modulations.**

Keywords: Viterbi and Viterbi- Fast acquisition- Jitter free tracking- Optimizer- Notch filter.

1. INTRODUCTION

In satellite communication systems it is desirable to use efficient modulations schemes such as M-PSK to satisfy the bandwidth limitations. An important issue in the design of the receiver in such systems is the detection and correction of Phase error in the received signal. Therefore, there is a need for phase synchronization in the receiver. By using the Viterbi and Viterbi as a PED, simulations show that there is a substantial amount of jitter in tacking mode. With implementing the optimizer after the PED, tracking mode will be almost jitter free and acquisition time will be very fast. Also Bit Error Rate performance (BER) will improve.

2. PERFORMANCE OF VITERBI AND VITERBI ALGORITHM WITHOUT OPTIMIZER

Viterbi and Viterbi algorithm has a Feed-Forward configuration [1]. For the best performance, fast acquisition and jitter free tacking has been expected but with reviewing simulation results of PED performance, it is obvious that there is a substantial amount of jitter in tracking mode. Fig. 1 shows the simulation result of PED performance without optimizer.

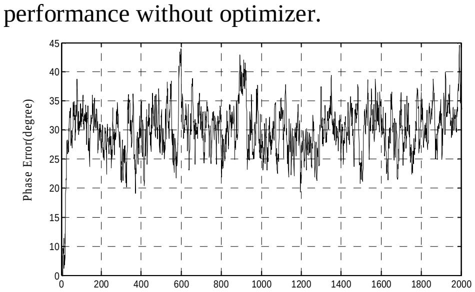

Fig.1: Tracking performance before optimization

A simple but powerful tool to investigate the performance of phase error tracking detector is the graph of power spectral density at DC ($fT = 0$) normalized to the square of the detector slope at equilibrium. To investigate the performance, the base band model of a Q-PSK modem with 50% rollof factor with the assumption of perfect frequency and timing synchronization was used. This graph was obtained in Fig. 2 for the Viterbi and Viterbi phase error detector algorithm. At $E_s / N_0 \geq 11dB$,The curve approaches the Cramer-Rao Bound (CRB) [2]

$$\sigma_\phi^2 = S(fT=0) \approx \frac{N_0}{2E_s}(2B_L T) \tag{1}$$

Where

$\sigma_\phi^2 = S(fT=0)$ is the loop noise spectrum at DC

E_s, N_0 are Energy per transmitted symbol and noise spectral density respectively

$B_L T$ is the loop noise bandwidth normalized to symbol period, T. Because Viterbi and Viterbi performance is poor (Fig. 2) to overcome this problem the optimizer has been developed. It is necessary to mention that in all of the simulations phase error is equal to 30 degree.

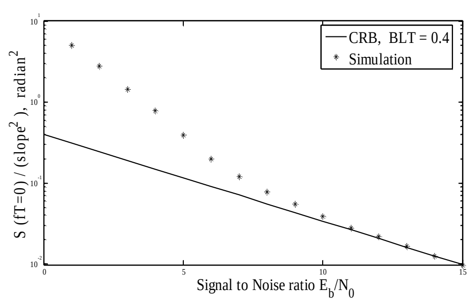

Fig.2: Noise Performance of Viterbi and Viterbi algorithm

It was assumed that the frequency synchronization and timing recovery were perfect. Fast acquisition is a prime objective in satellite communication but as it observed from Fig. 1 because of lots of jitters in tracking mode, it is not clear that when the error is acquired. Furthermore because of considerable amount of jitter in tracking mode, as will be shown shortly, result is unacceptable for BER performance.

In the next section the optimizer is introduced to reduce the tracking jitter.

3. OPTIMIZER

Fast acquisition is one of the main criteria in choosing a suitable error detection algorithm. However, increasing the tracking jitter, which, in return, deteriorates the bit error rate (BER) performance of the digital modem. In order to achieve a fast acquisition and an approximately jitter free tracking with the Viterbi and Viterbi algorithm the optimizer shown in Fig. 3 is added after the PED and makes really suitable performance.

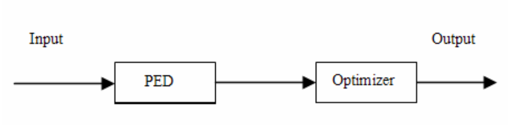

Fig.3: The position of optimizer

The suggested optimizer has been designed by using the Notch filter. The block diagram of implementing the optimizer has been shown in Fig. 4.

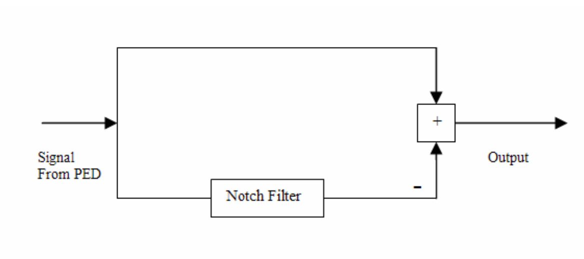

Fig.4: The block diagram of implementing the optimizer

In this suggested method, as it has been shown in Fig. 4, signal from PED passes through the notch filter. The notch filter which has the notch frequency in (f=0), passes all of the frequencies except that the frequency (f=0). After this step, output from the notch filter is subtracted of the signal from the PED. In this case the remained signal (output of the optimizer) has only a part in the DC (f=0) frequency. Consequently with viewing simulation results it will be shown that, the output of the optimizer has fast acquisition time (about 50 symbols). Also tracking mode is almost jitter free and this clear tracking helps us to define the acquisition time very obvious. Fig. 5 shows the output of Viterbi and Viterbi algorithm after optimization.

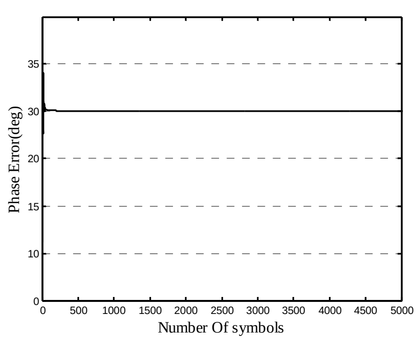

Fig.5: Tracking performance after optimization

PED performance has been presented for about 5000 symbols in Fig. 5. The phase error (30 degree) has been followed very fast and tracking mode is approximately without jitter.

4. TRANSFER FUNCTION OF THE OPTIMIZER

To find the transfer function for the optimizer, it seems that finding the transfer function for FIR notch filter is necessary. A notch filter is a filter that contains one or more deep notches or, ideally, perfect nulls in its frequency response characteristics. This notch frequency has been shown by w_0 .To create a null in frequency response of a filter w_0, it is simple to introduce a pair of complex-conjugate zeros on the unit circle at an angle w_0. That is

$$z_{1,2} = e^{\pm jw_0} \tag{2}$$

Thus the system function for an FIR notch filter is simply equals to (3).

$$H(z) = G(1 - e^{jw_0} z^{-1})(1 - e^{-jw_0} z^{-1}) \tag{3}$$

Where G is the gain value. With simplifying the above equation and considering the notch frequency at zero, the equation (4) will be concluded.

$$H(z) = G(1 - 2\cos w_0 z^{-1} + z^{-2}) \tag{4}$$

The problem with the FIR notch filter is that the notch has relatively large bandwidth, which means that other frequency components around the desired null are severely attenuated. To reduce the bandwidth of the null, a new transfer function is presented in an ad hoc manner, by introducing poles in the system function [3]. In this case suppose a pair complex-conjugate pole at

$$p_{1,2} = re^{\pm jw_0} \tag{5}$$

The effect of the poles is to introduce a resonance in the vicinity of the null and thus to reduce the bandwidth of the notch. Thus the system function for the resulting filter is

$$H(z) = G\frac{1 - 2\cos w_0 z^{-1} + z^{-2}}{1 - 2r\cos w_0 z^{-1} + r^2 z^{-2}} \tag{6}$$

where r has a direct effecting on the bandwidth of the notch frequency and changes between 0 and 1 and w_0 is 0 .The least bandwidth of the notch frequency occurs when r closes to 1and it is desired [4] . In this case the effect of the poles is to reduce the bandwidth of the notch. In addition to reduce the bandwidth of the notch, the introduction of a pole in the vicinity of the null may result in a small ripple in the passband of the filter, due to the resonance created by the pole. The effect of the ripple can be reduced by introducing additional poles and/or zeros in the system function of the notch filter. The major problem with this approach is that it is basically an ad hoc, trial-and-error method. After finding the notch filter transfer function, it is very simple to find the optimizer transfer function and frequency response. As it has been shown in Fig. 4, it is simple to find the total transfer function of the optimizer. Consequently the optimizer transfer function is

$$H(z) = G\frac{2z^{-1}(1-r) + z^{-2}(r^2 - 1)}{1 - 2rz^{-1} + r^2 z^{-2}} \tag{7}$$

$$H(w) = (r-1)\left[\frac{(-2\cos w + (r+1)\cos 2w)}{(1-2r\cos w + r^2\cos 2w) + j(2r\sin w - r^2\sin 2w)}\right]$$
$$+ (r-1)\left[j\frac{(2\sin w - (r+1)\sin 2w)]}{(1-2r\cos w + r^2\cos 2w) + j(2r\sin w - r^2\sin 2w)}\right] \quad (8)$$

The equation (8) shows the frequency response of the optimizer.

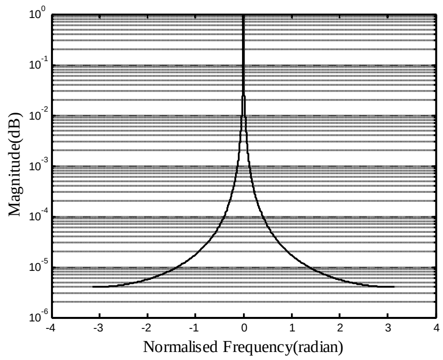

Fig.6: Frequency response of optimizer

Frequency response of the optimizer has been shown for r=0.98.

5. BIT ERROR RATE PERFORMANCE

Bit error rate (BER) performance of the modem before and after optimization in the phase error synchronization loop is shown in Fig. 7. It is observed that under the same channel conditions, the BER performance of the optimized modem approaches the theoretical results which are equal to (9) while the performance of the original Viterbi and Viterbi algorithm is unacceptably poor.

$$0.5\, erfc\ \sqrt{\frac{E_b}{N_0}} \quad (9)$$

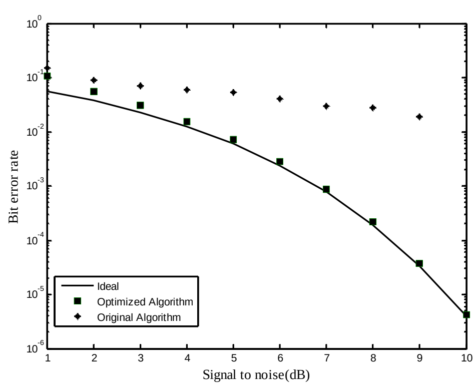

Fig.7: BER performance

It is observed from Fig. 7 that BER performance of the optimized Viterbi and Viterbi algorithm has improved and is very close to the theoretical result.

6. OPTIMIZED PED PERFORMANCE WITH B-PSK

The performance of Viterbi and Viterbi phase error detector without optimizer has substantial amount of jitter in all kinds of M-PSK modulations, but simulation results show that after optimization tracking performance and acquisition time will be improved greatly. Although this result is true about all kinds of M-PSK modulations but for simplicity the performance of PED has been shown for B-PSK before and after optimization.

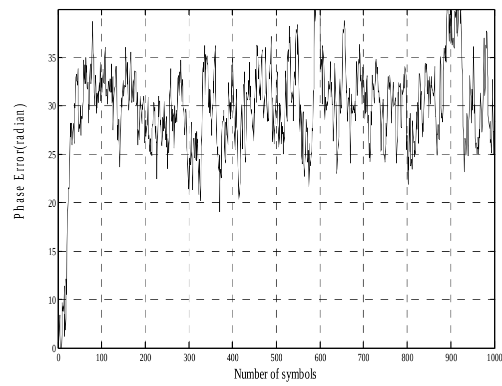

Fig.8: Tracking performance before optimization with B-PSK

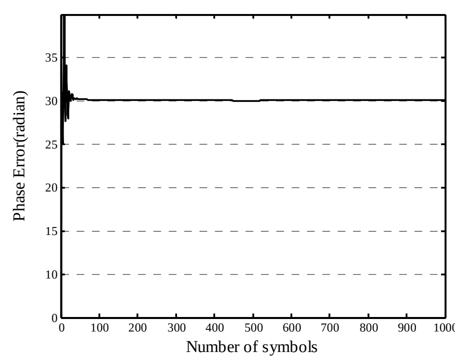

Fig.9: Tracking performance after optimization with B-PSK

7. CONCLUSIONS

In this paper, the tracking performance of the Viterbi and Viterbi phase error detection algorithm was optimized. Using the optimizer was designed with a notch filter with a notch frequency in (f=0), an approximately jitter free tracking has been achieved. The simple feature and short acquisition time and jitter free tracking in all kinds of M-PSK modulations, make our approach suitable for fast applications such as those in satellite communications.

8. REFERENCES

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