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Elimination of Cycle Slipping and Effect of Transmission Delay in Heterodyne PLL Demodulator

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Abstract
The present paper reports interesting results on elimination of cycle slipping phenomenon in a heterodyne or a long loop PLL demodulator complicated by the presence of transmission delay in the system. The analysis has been performed in Mathematica. A novel heterodyne PLL is proposed that eliminates this annoying effect.

Keywords
Cycle Slipping; Phase Modulator Gain; Transmission Delay

I. Introduction

The origin of phase locking technique goes back to the times of Huygens, when he observed the phenomenon of synchronization of two pendulums hung on a thin wooden plank. The present form of phase locking was observed by H. de Bollesize in 1932 through an automatic phase control circuit, presently known as a Phase Locked Loop (PLL).

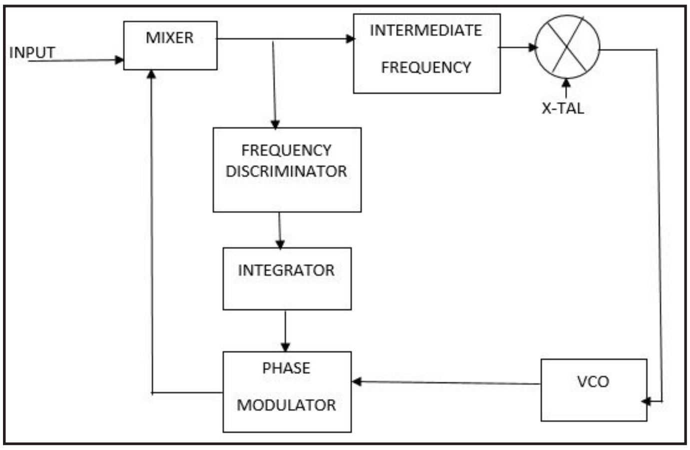


Fig. 1: Block Diagram of the Proposed PLL

Conventional PLL generally consists of a phase detector, low pass filter and a voltage controlled oscillator [1]. Unlike the conventional simple PLL the present form is a standard heterodyne or a long loop PLL [2] except with an additional frequency discriminator as depicted in Fig. 1. The output of the discriminator after passage through an integrator modulates the output of the Voltage Controlled Oscillator (VCO). The mixer output after filtering through a band pass filter (BPF) is phase compared with the instantaneous of phase of an X-tal oscillator. The low pass output of the phase detector controls the instantaneous frequency of the VCO. The incorporation of the BPF produces a delay (usually called transmission delay but unlike the delay in an optoelectronic oscillator) gives rise to various annoying phenomena.

In the present paper we consider its effect on the demodulation capability of a PLL demodulator and how to improve upon the demodulation characteristics of such a loop. For the simulation study we have used MathCAD software but modified it for incorporating the effect of delay in the loops (Modification of Euler Method and standard MCAD procedures).

This proposed PLL structure is able to eliminate the cycle slipping along with the demodulation error that arises from the transmission delay as shown in the following results. Euler's forward algorithm [3] has been used here for analysis as the PLL structure is the closed loop forward control system [4] where the results of previous instant is fed back for computation of the next instant value which is the basis of forward algorithm.

Mathematical Analysis

It can be easily shown that (Fig. 1)

$$\frac{d\varphi}{dt} = \Omega(1-K_d) - K\sin\phi(t-\tau) + \frac{d\psi}{dt} \qquad (1)$$

where

$$\frac{d\psi}{dt} = \Delta\cos(\omega t)\,,\ \Delta = \text{frequency deviation}$$

where,

Ω= Open loop frequency error between the two oscillations

ϕ Phase difference between the local oscillator and the external signal

K= Open loop gain

τ= The transmission delay

ψ= Angle modulation

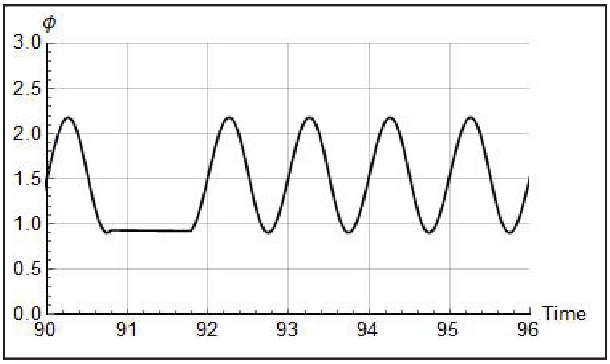
K_d= Phase detector constant

The concept of cycle slipping phenomenon may be explained as thus [1]. In the absence of additive random noise, the loop is locked to the incoming signal without any steady state phase error. But if the incoming signal becomes corrupted in the presence of additive random noise there is a phase jitter at $\phi = 0$. When the amplitude of the noise becomes large, it may increase the phase error beyond $\pm\pi/2$ radians and the loop may be thrown out of lock. However, since the amplitude of noise does not remain large all the time and since the synchronizing signal will always act as a restoring force to bring the loop to the locked state, the loop will be ultimately brought back to lock, but the locking will not be at $\phi = 0$ but around $\phi = 2\pi n$ or $\phi = -2\pi n$ depending upon the initial throw either to $\phi = \pi/2$ or $\phi = -\pi/2$. In doing this, the loop gain drops a cycle relative to the incoming signal, hence the name cycle slipping. To verify the cycle slipping phenomena and effect of transmission delay we have operated the loop on the verge of loosing lock with some open loop frequency error and with frequency modulated input signal.

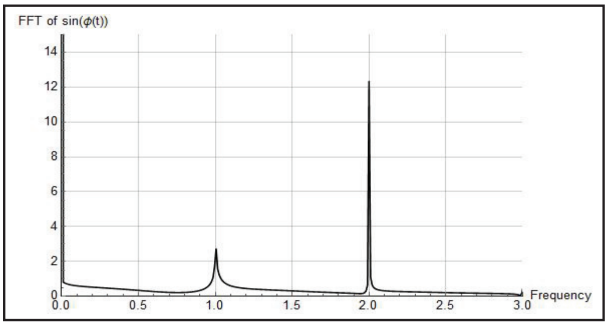
III. Results and Discussion

Let us first observe the phenomena in the absence of K_d. The loop presented in fig. 1 is operated in such a way (by suitably adjusting the parameters) that cycle slipping occurs (Fig. 2(a)). The frequency response shows that the amplitude of second harmonics is more than that of first harmonics (Fig. 2(b)). The effect of frequency deviation has a marked effect on cycle slipping phenomena. The cycle slipping phenomena is observed for high value of frequency deviation, say $\Delta = 4$ (Fig. 3). The loop never tries to attain lock. But when frequency deviation is reduced, say

$\Delta = 1$, then the loop is locked and no cycle slipping phenomena is observed (Fig. 5). Moreover when K_d is introduced, even then cycle slipping is eliminated (Fig. 4). Even the transmission delay has a marked effect on the cycle slipping phenomena (Fig. 6). With increase in the transmission delay, the effect on the cycle slipping phenomena becomes more and more pronounced (Fig. 6).

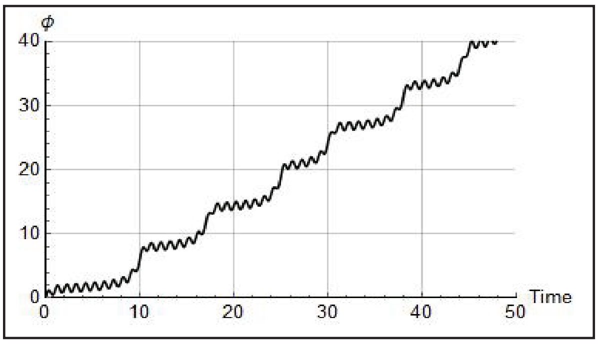


(a)

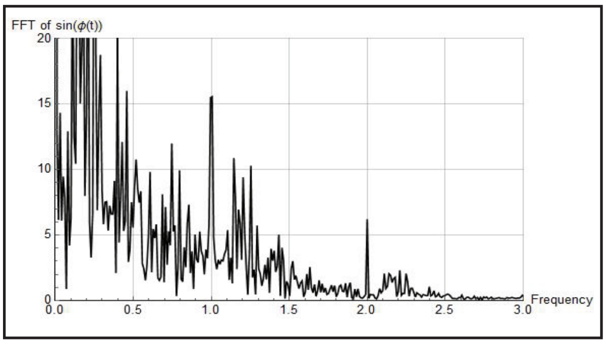


(b)

Fig. 2. Phase detector output (a) and its frequency response (b) showing cycle slipping phenomenon (K=2, τ=0.48, Δ=4, $\Omega = 1.8$ $K_d = 0$, $\omega = 2\pi \cdot 1$)

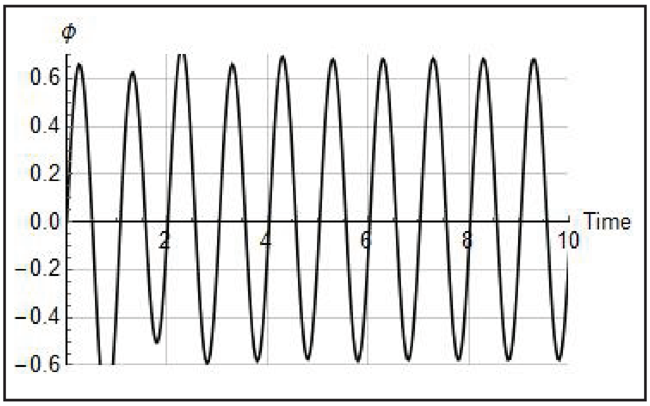


(a)

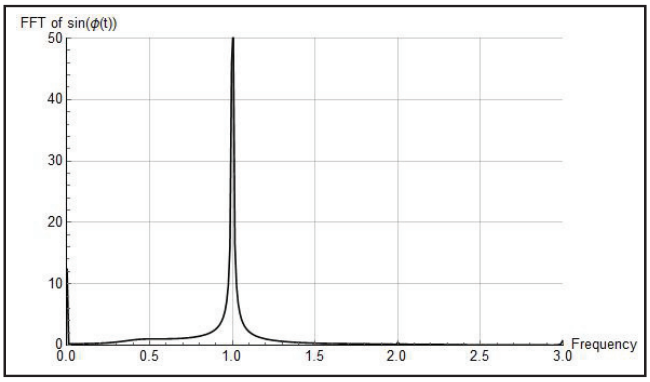


(b)

Fig. 3: Phase detector output (a) and its frequency response (b) showing cycle slipping phenomenon (K=2, τ=0.48, Δ=4, $K_d = 0$ $\Omega = 1.9$, $\omega = 2\pi \cdot 1$)

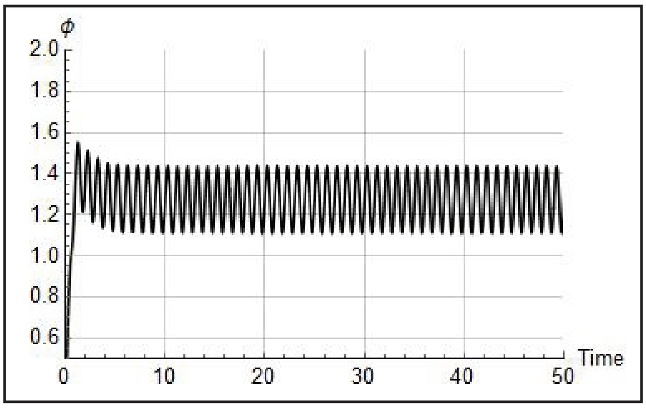


(a)

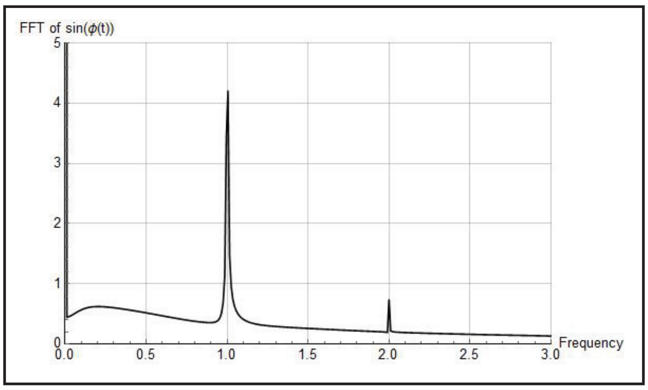


(b)

Fig. 4. Phase detector output (a) and its frequency response (b) showing cycle slipping phenomenon (K=2, τ=0.48, Δ=4, K_d = 0.95, $\Omega = 1.9$, $\omega = 2\pi \cdot 1$)



(a)



(b)

Fig. 5. Phase detector output (a) and its frequency response (b) showing cycle slipping phenomenon (K=2, τ=0.48, Δ=1, $K_d = 0$ $\Omega = 1.9$, $\omega = 2\pi \cdot 1$

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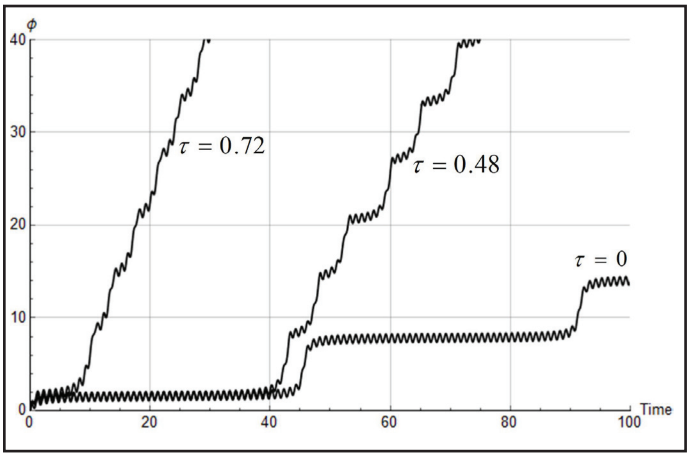

Fig. 6: Phase Detector Output (a) and its Frequency Response (b) showing cycle slipping phenomenon (K=2, τ =0.48, Δ =2.9, $K_d = 0$, $\Omega = 1.9$, $\omega = 2\pi \cdot 1$)

IV. Conclusion

It is thus concluded that cycle slipping phenomena is not observed when frequency deviation is low. But when the frequency deviation is increased (keeping other parameters constant) then cycle slipping phenomena is observed. Transmission delay also has effect on the extent of cycle slipping. Even the presence of K_d eliminates cycle slipping.

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