

Novel Extended Range Phase-Lock Demodulator With Injection Feedback

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Abstract

In this a novel tracking heterodyne phase locked loop is presented with numerical simulation results. It avoids false locking, reduces noise bandwidth, improves the modulation handling capability and improves transient response considerably.

Keywords

extended Range PLL; False-locking; Noise Bandwidth; Transient Response; Injection Locking

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 Bellescise in 1932 through an automatic phase control circuit, presently known as a Phase Locked Loop (PLL). A phase-locked loop or phase lock loop (PLL) is a control system that generates an output signal whose phase is related to the phase of an input signal. As a matter of fact, in 1932 a scientist in France by the name of H. de Bellescise, already wrote a subject on the findings of PLL called "La Réception Synchrone", published in Onde Electrique, [2]. We guess he lacked the funding or did not know how to implement his findings. In either case it is our personal belief that the British scientist team developed further on the findings of Bellescise. No problem, good stuff. That's why papers like Bellescise are there for. Phase Locked Demodulators (PLD) has gained widespread acceptance in recent years [3-4]. But it suffers from the following disadvantages:

1. Recently heterodyned version of the PLL is used to improve the output SNR. But it introduces transmission delay into the governing system equation. As a result, it affects the locking behavior and often leads to false locking. The equivalent noise bandwidth increases thereby reducing locking range.
2. It also reduces phase locking that increases the cycle slipping rate, and thus it generates spike noise reducing SNR at the output.

In order to overcome these defects a new phase locked system, extended range phase-locked demodulator (ERPLD) is proposed. The modified loop called novel ERPLD is shown in Fig. 1. It consists of the following components:

- A phase modulator which modulates the output of the VCO.
- Two IF circuits: one broadband and the other narrowband. The wideband IF circuit is used to injection lock the narrowband oscillator. The narrowband IF circuit feeds the phase detector.

In the following analysis we have assumed that the receiver captures the transmitted signal with no noise, no distortion and no channel delay. In future communication these will be taken care of.

A. Historical Background

The extended range PLD (ERPLD) was proposed by Acompora and Newton in 1966 [1]. It is interesting to note that B. N. Biswas and N. B. Chakraborty gave the idea in a personal memorandum in 1964 at the Calcutta University. Later on a Russian author also reported a similar work. These are all baseband PLL. In subsequent years, heterodyne PLL was realized where the phenomenon of false locking was reported, but the method of elimination of was not reported. The modified loop called novel ERPLD is shown in Fig. 1.

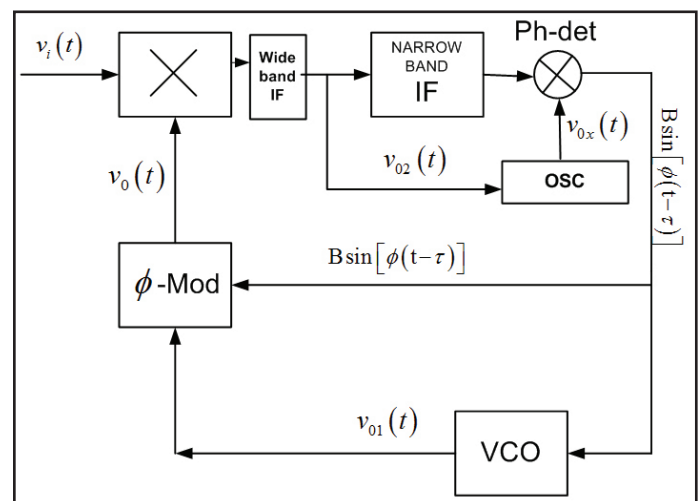


Fig. 1: Extended Range PLD

II. Derivation of the System Governing Equation

Referring to the proposed model for the modified ERPLD shown in Fig. 1, let us assume the input to the ERPLD as $v_i(t) = A \sin[\omega_i t + \psi(t)]$, the output of the VCO as $v_{01}(t) = 2 \cos[\omega_0 t + \theta(t)]$. The output of the phase modulator feeding the mixer is assumed to be $v_0(t) = 2 \cos[\omega_0 t + \theta(t) + \beta(t)]$, where ' $\beta(t)$ ' arises because of the phase modulation of the VCO. Finally, the input and the output to the oscillator is given by $v_{02}(t) = E \cos[\omega_{if} t + \psi(t) - \theta(t) - \beta(t)]$ and $v_{0x}(t) = B \sin[\omega_0 t + \theta_{0x}(t)]$ respectively.

Hence, it is not difficult to show that

$\frac{d\theta_{0x}(t)}{dt} = \left(\frac{\omega_0}{2Q} \frac{E}{B} \right) \times \sin[\varphi(t)]$ and the governing equation of the system is given by

$$\frac{d}{dt}\phi(t) = \Omega - K \sin[\phi(t)] - \frac{d}{dt}\{K_p \sin[\phi(t)]\} - \left(\frac{\omega_0 E}{2Q B}\right) \times \sin[\phi(t)] + \frac{d\psi}{dt};$$

where $\phi(t)$ is the phase difference between the input and the output and is given by

$$\phi(t) = \omega_y t + \psi(t) - \theta(t) - \beta(t) - \omega_0 t - \theta_{0x}(t)$$

It is to be noted that (i) E is the amplitude of the injection signal (ii) B is the oscillator output amplitude, (iii) Q is the quality factor of the tuned circuit and (iv) the free running frequency of the oscillator is ω_0 , (iv) A is the input signal strength .

III. Numerical Experiment and Conclusions

Fig. 2 shows that the possibility of false locking is considerably reduced in the proposed system. Fig. 3 shows the noise bandwidth is considerably reduced. Fig. 4 indicates excellent performance of the modified loop as FM demodulator. Fig. 5 and Fig. 6 confirm the performance of the FM demodulator through FFT analysis at the output. It is worthwhile at this point to mention that Fig. 2 is obtained using MATHCAD 14.0 software while Figs. 3-7 are obtained using MATHEMATICA 11.0 software.

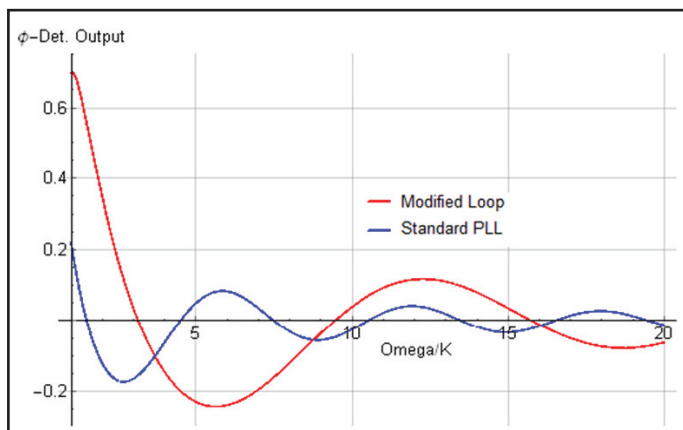


Fig. 2: False locking in extended range PLD

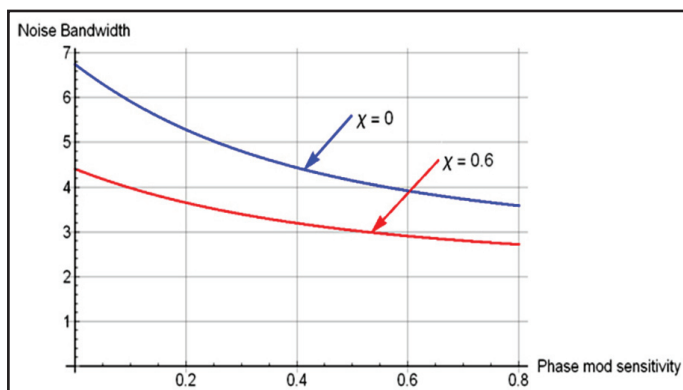


Fig. 3: Noise bandwidth in extended range PLD for different injection levels

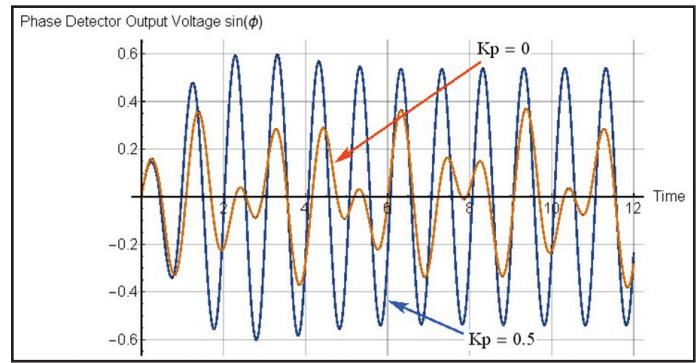


Fig. 4: Demodulation in extended range PLD for different phase modulation sensitivity

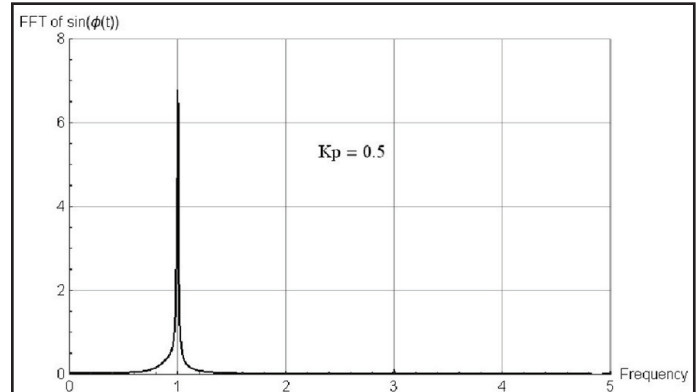


Fig. 5: FFT of phase detector output in extended range PLD; X=6

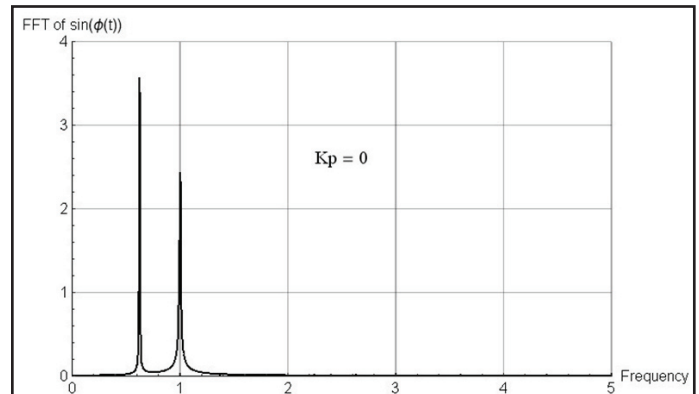


Fig. 6: FFT of phase detector output in extended range PLD, X=0

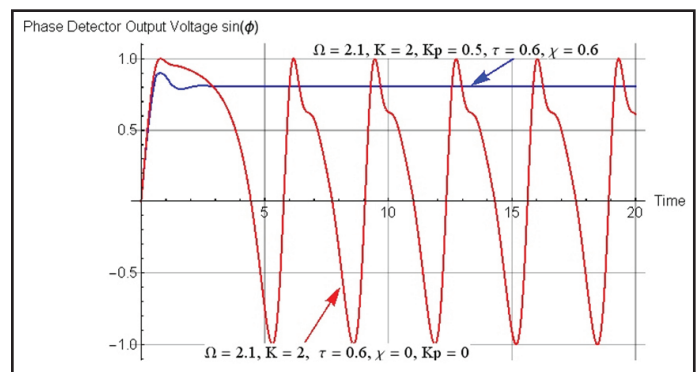
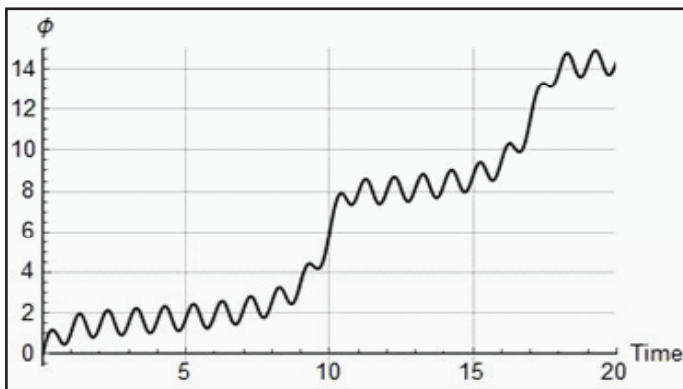


Fig. 7: Transient response of the extended range PLD

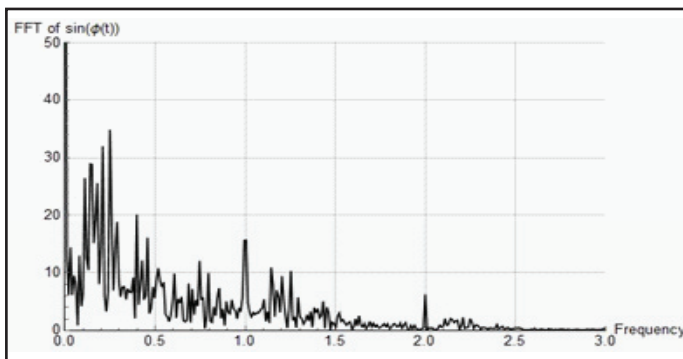
IV. Cycle Slipping and Chaotic Behaviour

When a heterodyne phase locked demodulator is tracking an FM signal with large index of modulation, it slips cycle in chaotic fashion particularly when the loop is very narrow (Fig. 8). But in

our modified configuration by controlling the discriminator gain the chaotic loop can be easily brought back to order. These are illustrated in Fig. 9.

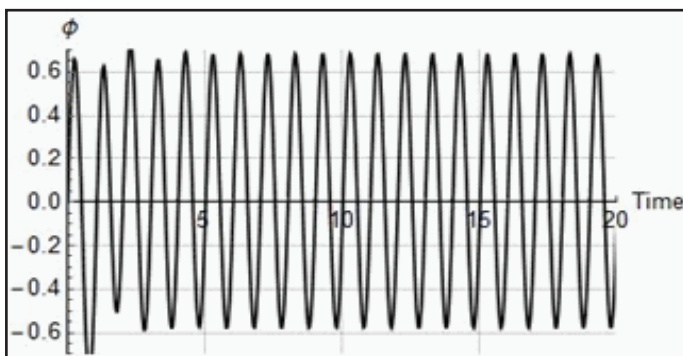


(a)

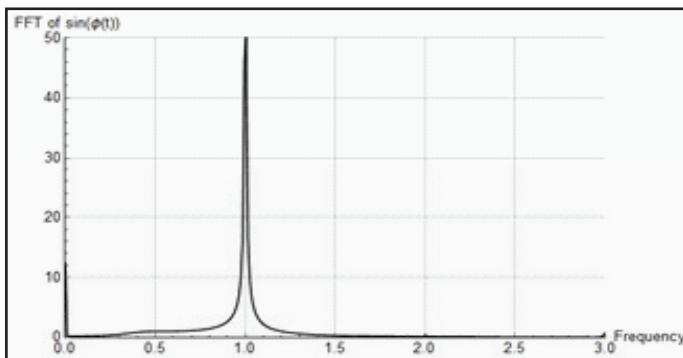


(b)

Fig. 8: Plot of Phase Difference ϕ (a) and its frequency response (b) showing the effect of cycle slipping phenomenon ($K=2$, $\tau=0.48$, $\Delta=4$, $K_d=0.0$, $\Omega=1.9$, $\omega=2\pi \cdot 1$)



(a)



(b)

Fig. 9 Plot of phase difference ϕ (a) and its frequency response (b) showing the effect of cycle slipping phenomenon ($K=2$, $\tau=0.48$, $\Delta=4$, $K_d=0.0$, $\Omega=1.9$, $\omega=2\pi \cdot 1$)

V. Conclusion

A novel ERPLD is presented. The system governing equation of the ERPLD is presented and the effect of phase modulator is studied on the noise bandwidth and the transient response of the system. The modified ERPLD acts as an excellent demodulator and it has been verified that the phase modulation sensitivity improves considerably the demodulation characteristics of the system. This is verified again by observing the FFT at the output of the phase detector. It is also concluded that in the modified loop presented, cycle slipping phenomenon can be avoided by controlling the discriminator gain.

VI. Acknowledgment

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References

- [1] A Acampora, A Newton, "Use of Phase Subtraction to Extend the Range of a Phase-Locked Demodulator", RCA Review, 27, No. 4, December 1966, pp. 577-599. J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., Vol. 2. Oxford: Clarendon, pp. 68-73, 1892.
- [2] H. de Bellescise, "La réception Synchrone", Onde Electrique, Vol. 11, 1932. K. Elissa, "Title of paper if known," unpublished.
- [3] B N Biswas, "Phase Lock Theories And Application", Oxford & IBH, New Delhi, 1988.
- [4] F M Gardner, "Phase Lock Techniques", Third Edition, Wiley, 2005. M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.