A TRACKING SOFTWARE DEFINED FILTER

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Abstract
A tracking software defined filter (TSDF), while achieving the job of a filter, tracks the instantaneous phase or frequency of the incoming signal. The filter parameters can be easily adjusted through software control. This makes the system most suitable for adaptive system. The TSDF consists almost identical components except that that it incorporates an I-Q phase detector and an additional phase modulator. This modification improves the response characteristic of the filter to a great extent, which has been supported by the simulation results.

TSDF-STRUCTURE

The structural configuration of the system where tracking software defined filter is depicted below. The TSDF is preceded by an arrangement that generates in-phase and quadrature components at a frequency suitable from the RF or microwave signals with a view not to cross the speed limit of DSP-LSI chips. This is shown in Fig.1.

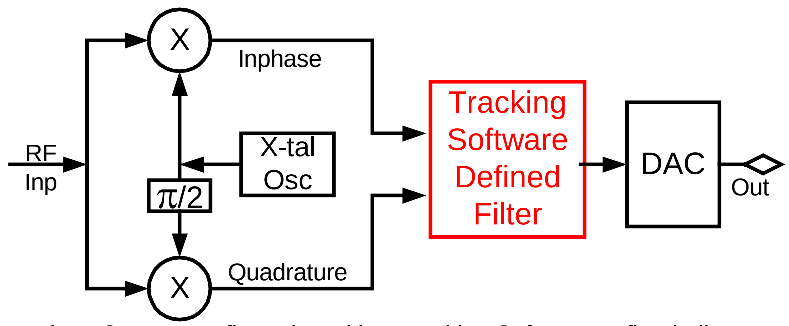

Fig.1: System configuration with a Tracking Software Defined Filter

It consists of a balanced phase detector, a phase modulator, a digital filter and a numerically controlled oscillator. The beauty of the balanced phase detector is that it does need low pass filter to suppress the sum frequency component. Moreover, it does not introduce initial transient error. The interesting feature of the proposed tracking software defined filter is that it incorporates an additional phase modulator at the output of the digital voltage controlled oscillator. This additional phase modulator effectively reduces the phase error between the input and output signals thereby increasing the phase tracking capability of the system. As a result it is expected to reduce the cycle slipping rate when responding to a noisy signal.

SYSTEM EQUATION

The In-phase and Quadrature components of the input signal and outputs of the voltage-controlled numerical oscillator are assumed to be the forms

$$X_i(k) = A\sin\theta(k)$$
$$X_Q(k) = A\cos\theta(k)$$

(1)

and

$$W_I(k) = \sin\psi(k)$$
$$W_Q(k) = \cos\psi(k)$$

Hence referring to Fig. 2, the phase detector output is given by

$$Y(k) = A\sin\phi(k) \qquad (2)$$

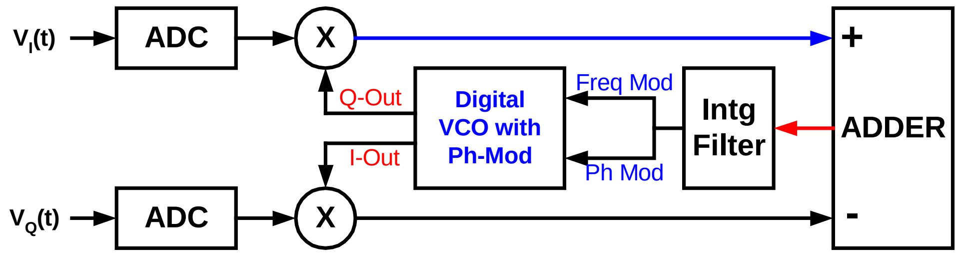

Fig.2: Block diagram of a tracking digital filter

Note that

$$\theta(k) = \frac{2\pi f_1 k}{f_s} + \psi_1(k)$$
$$\psi(k) = \frac{2\pi f_2 k}{f_s} + \psi_2(k) \qquad (3)$$

Where $\psi_1(k)$ input modulation and $\psi_2(k)$ is given by

$$\psi_2(k) = \psi_2(k-1) + KY(k-1) + K_P Y(k-1) \qquad (4)$$

If 'K' is the sensitivity of the VCO and 'K_P' is the sensitivity of the phase modulator gain, $\phi(k)$ is the phase error between the input and output at the kth instant then

$$\phi(k) = \theta(k) - \psi(k)$$

Therefore, the governing phase equation is conveniently written as

$$\phi(k) - \phi(k-1) = \Omega - AKF(z)\sin\phi(k-1) - AK_P[\sin\phi(k) - \sin\phi(k-1)] \qquad (5)$$

Where $\Omega = \dfrac{2\pi(f_1 - f_2)}{f_s}$

The transfer function of a 1st order digital filter is

$$F(z) = a + \frac{b}{1 - z^{-1}} \qquad (6)$$

Therefore, the above phase equation (5) can be written as (mixed notation)

$$\phi(k) - \phi(k-1) = \Omega - AK\left(a + \frac{b}{1 - z^{-1}}\right)\sin\phi(k-1) - AK_P[\sin\phi(k) - \sin\phi(k-1)] \qquad (7)$$

Noting that here, $\psi_1(k-1) = \psi_1(k)$, one can express (7) as

$$\phi(k) - 2\phi(k-1) + \phi(k-2) = -AK(a+b)\sin\phi(k-1) + AK\sin\phi(k-2) - K_p\left(\sin\phi(k) - 2\sin\phi(k-1) + \sin\phi(k-2)\right) \quad (8)$$

Hence, it is seen that in the steady state,

$$\phi(k) = \phi(k-1) = \phi(k-2) = \phi_s$$
$$-AKb\sin\phi_s = 0$$

i.e. $\phi_s = 0$

Thus, a second order tracking digital filter locks on to a frequency step signal with zero steady state phase error. Now the fact is that it takes time to look onto the signal, which depends on the value of, the open loop frequency error and the loop gain AK. Higher the value of AK lower is the locking time. Now the question is: How far can we increase the value of the open loop gain AK? Unlike the second order analog phase locked loop, which is unconditionally stable, the second order DPLL is conditionally stable. That is, when

$$AK \le \frac{4}{2a+b} \quad (9)$$

Referring to the above equations it is not difficult to show that for the TSDF the stability condition comes out to be

$$AK \le \frac{4(1+AK_p)}{2a+b} \quad (10)$$

Therefore, an increase of the gain of the phase modulator can considerably increase the loop gain. For example, if AK_p=1.0, then the loop gain of the TSDF is twice that of the conventional DPLL.

NUMERICAL EXPERIMENT

The TSDF is simulated on MATLAB SIMULINK and the result observed on the stability and performance is shown

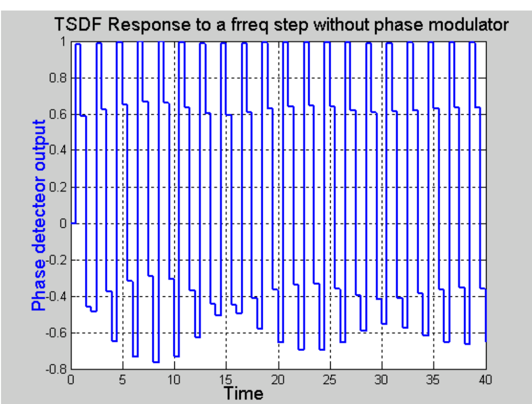

Fig.3: Freq step response of the TSDF without the phase modulator

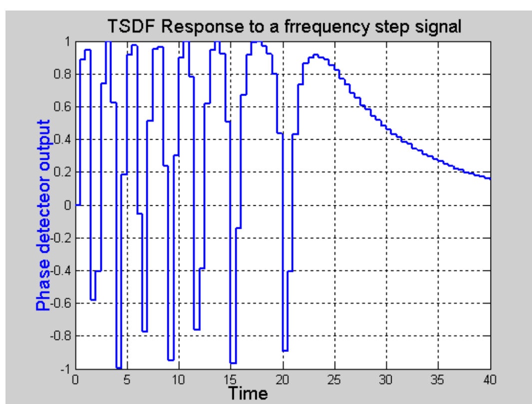

Fig.4: Frequency step response of the TSDF with the phase modulator

depicted in Fig.3 and Fig.4 respectively showing perfect agreement with the theoretical conclusions.

CONCLUSION

The Tracking Software Defined Filter was simulated using MATLAB and the response of the TSDF to a frequency step signal with an appropriate value of the phase modulator gain is shown in Fig.3 and is compared with that of a standard digital phase locked loop without the phase modulator in Fig.4. A marked difference is observed – showing perfect tracking. From this it can be concluded that a TSDF cane be used a tracking demodulator of an FM signal with large signal handling capability.

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