OPTIMAL PHASE SHIFT METER ON THE BASIS OF KALMAN'S FILTER IN MULTIPATH CHANNEL SYSTEMS

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A formalization of optimal radio signal's phase evaluation task has been provided in this work. As well as radio signal's optimal phase shift device modelling on the basis of Kalman's filter has been made. Therewith precise characteristics of Kalman's filter were defined when radio signal's phase (that is taken under multi-path propagation conditions with quasi-harmonic narrowband interferences) is estimated.

Keywords: *phase shift meter, vectorial Kalman's filter, precise characteristics*

One of the most actual values that have to be clarified in modern radio navigation is the problem of getting navigation value (phase shift, time delay, angle etc.) with minimal error and with maximum accuracy.

When a meter is designed some prior information about conditions of signal and noises in the reception point has to be known. Moreover taken conditions have to be very close to real.

The problem of getting precise value of signal's parameters grows up in a selective fading environment that is caused by multipath radio wave's propagation. Selective fading are stronger in real channels, such as decametre and hectometre channels with ionosphere scatter propagation.

In navigation systems there are methods of secondary filtration that help to prevent multipath effect as well as abnormal errors. Method of secondary filtration is based on filtration of different values of one and the same parameter that were procured by various meters (not optimal). It is also used to use a Kalman's vector filter [3] as a secondary one.

More rarely an optimal meter of concrete navigation parameter with prior information about conditions of signal and noises in reception point is taken into consideration. For example, it is very difficult to optimize phase shift meters in high-accuracy hectometre radio navigation systems.

Let's have a look at the possibility to create optimal phase shift meter on the base of scalar Kalman's filter [2] for hectometre radio navigation systems taking into consideration signal's propagation way.

As the result of formalization of the task of getting optimal value of radio signal's phase [4] we could find the following. When we use extended Kalman's filter in the systems with adaptive filtration, then we have phase-lock loop (PLL) circuit instead of HF-signal phase estimation. On Figure 1 the simplified PLL system's circuit is shown:

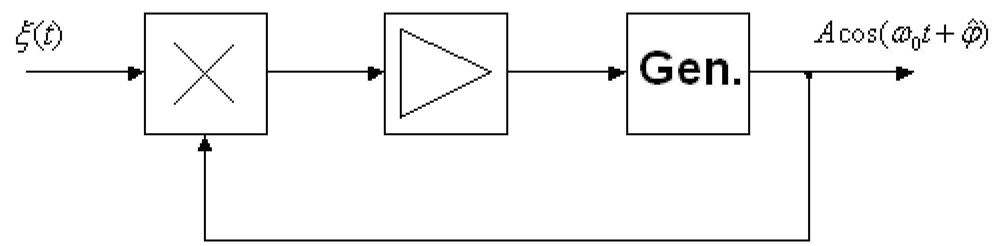

Figure 1. *Simplified PLL system circuit*

If we simplify a model of signal generation, the generator at the transmitting side will generate the following sinusoidal vibration

$s(t,\varphi) = A\sin(\omega_0 t + \varphi)$.

At the receiving point we'll have the desired signal which is added with a noise $n_0(t)$:

$\xi(t) = A\sin(\omega_0 t + \varphi) + n_0(t)$.

In this circuit there are 3 main units:

- Demodulator (after multiplying input signal with a feedback circuit signal it gets LF component – received signal's and generator's frequency beats in PLL, as well as harmonic at $2\omega_0$ frequency).
- Circuit unit that performs the following functions: amplifying, generating (shaping) filter and phase evaluation device. It helps us to avoid a high frequency harmonic as well as to get optimal phase value.
- High frequency generator $A\cos(\omega_0 t + \varphi)$ which phase is modulated with the help of controlled deviation $d\hat{\varphi}/dt$ (that is in proportion to $A\cos(\omega_0 t + \hat{\varphi})$ and $\xi(t)$ product).

When optimal phase evaluation device on the basis of Kalman's filter [1] of radio signal has been modelled, its precision curves were experimentally evaluated.

You can find on Figure 2 a circuit that evaluates precision curves of Kalman's filter. There you can see two measuring channels: standard channel (without any noises) and estimated channel.

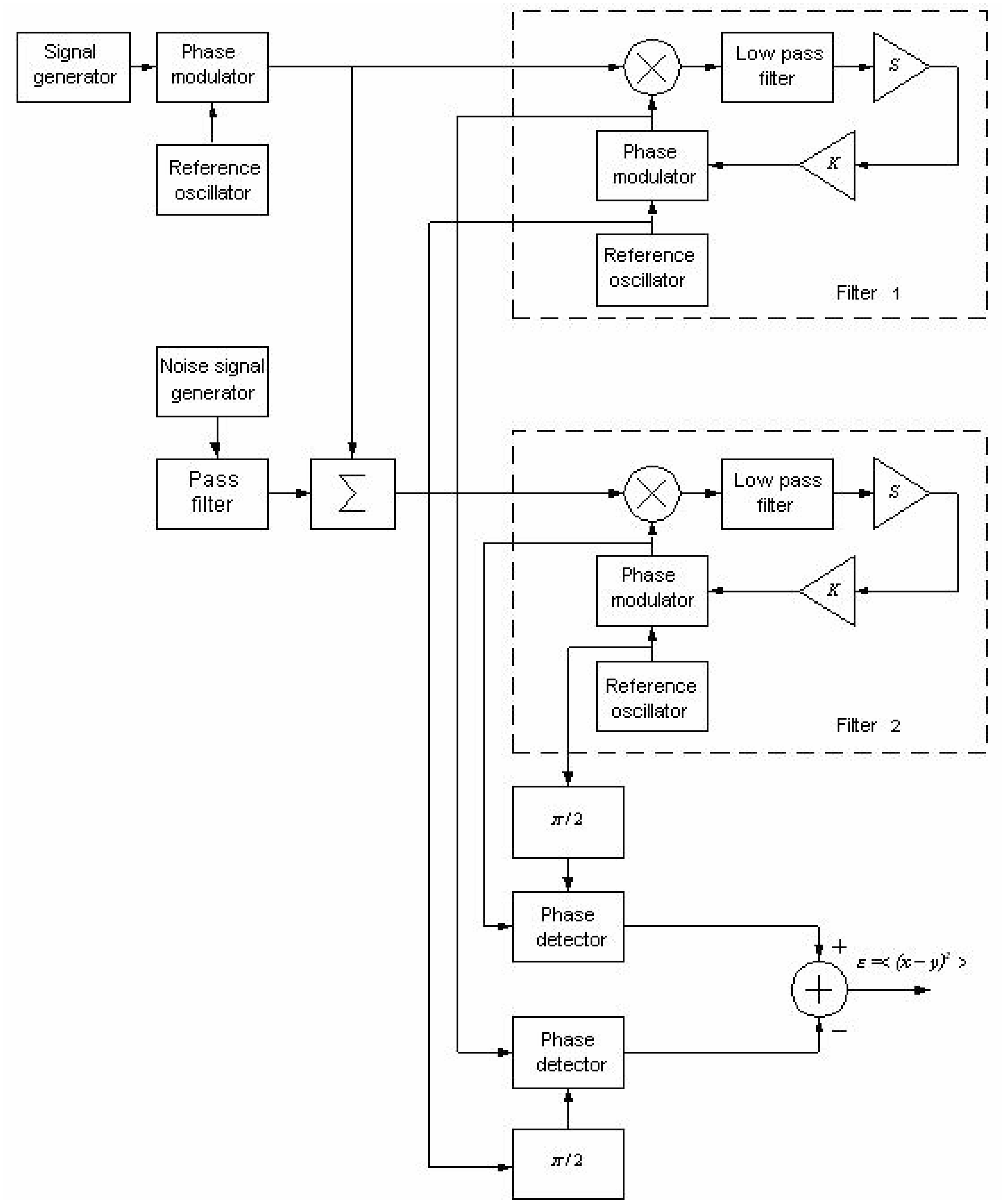

Figure 2. *Kalman's filter precise characteristic's evaluation circuit*

In this circuit the evaluation of precise characteristics of Kalman's filter (when a signal is under different noise power) has been made. For such evaluation it is needed to have relationship between phase shift evaluation one-sigma value in the channel with noises and evaluation of signal/noise ratio in standard channel.

The following precise characteristics of Kalman's filter have been evaluated:

- in comparison with precise characteristics of the meter at the basis of balance phase detector when it receives radio signal with a normal white noise,
- when radio signal is received with narrow-band quasi-harmonic interference,
- when radio signal is received with multipath radio waves propagation conditions.

When precise characteristics of Kalman's filter were evaluated in conditions of multipath radio waves propagation, the received signal was generated with the help of two channels. One of them is direct channel and the second one – multipath channel, where some rays are reflected from ionosphere.

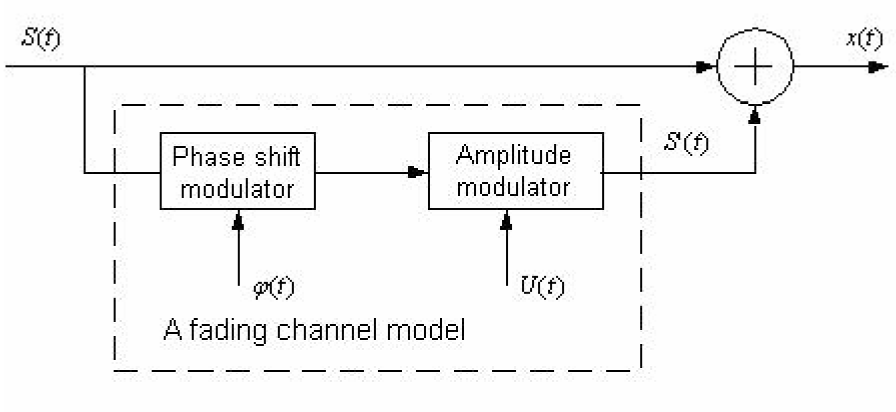

Figure 3. *A circuit of fading channel modelling*

On Figure 3 you can see a circuit of signal's generation that goes through a fading channel. Where S(t) – is HF vibration that has been modulated with information signal. The influence of φ(t) and U(t) at the signal changes the phase and the amplitude of the signal's envelope according to amplitude and phase shift laws in fading channels. So, in this way we can model a signal that goes through multipath channel. We are getting the sum signal after adding signal from direct channel S(t) to the signal from multipath channel x(t).

So, now it is possible to evaluate precise characteristics of Kalman's filter as follows. We can find dependence between phase shift evaluation one-sigma value in multipath channel and relationship between power of direct channel signal S(t) with multipath channel signal x(t) in standard channel.

Reposing on experimental data that were received after modelling of the meter at the basis of Kalman's filter we can conclude the following:

- Probability density function law of the noise envelope doesn't influence on precision of the value of phase shift optimal meter;
- Location of centre frequency of the quasi-harmonic interference doesn't influence on accuracy of signal's parameters evaluation practically;
- Usage of Kalman's filter helps to improve the accuracy of phase shift evaluation almost in two times (comparing with balance phase detector based meter);
- Influence of multipath channel is equal to narrow-band quasi-harmonic interference. And it doesn't depend on probability density function law (Gauss or Rayleigh) of vibration envelope at the output of multipath channel.

For last conclusion illustration there are figures of one-sigma value of the phase shift evaluation available on Figure 4. It was taken when relationship between signals power in direct channel and in multipath fading channel was changed and when relationship between signal and noise in a channel with narrow-band quasi-harmonic interference (a channel without fading) was also changed.

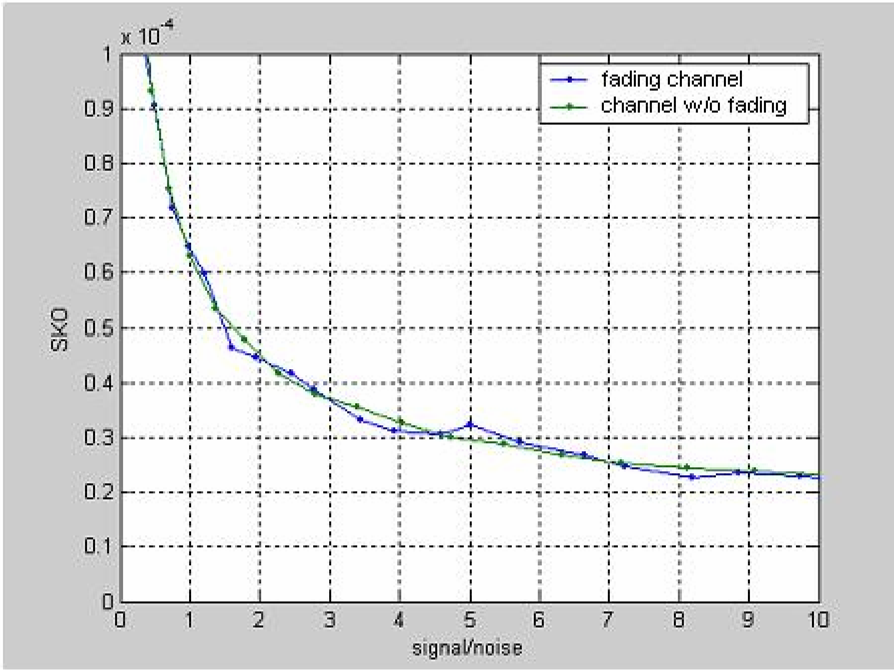

Figure 4. *Figures of one-sigma value of the phase shift evaluation in fading channels and in channels without fading*

References

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