ISSN 0735-2727, Radioelectronics and Communications Systems, 2012, Vol. 55, No. 2, pp. 75–81. © Allerton Press, Inc., 2012.
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# Phase Recovery of the Coherent Carrier Frequency in Synchronous Detection

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Received in final form February 13, 2012

**Abstract**—This paper considers a method of phase recovery in synchronous detectors that ensure the synchronous detection of signals with amplitude modulation, amplitude-phase modulation, angle modulation or with appropriate manipulations. In addition a transfer function was obtained for the phase-locked loop of direct control and the simulation results of modeling were also presented.

**DOI:** 10.3103/S0735272712020033

Nowadays synchronous detectors are applied in many different systems for ensuring the high-quality detection. These detectors require practically exact coincidence of phases of the detectable signal and the reference generator signal that is achieved by applying the phase-locked loop frequency control (PLL) units [1–3]. The application of PLL units limits the rate of phase control due to the presence of low-pass filters (LPF) being lag elements. Due to the above reasons the application of synchronous detectors [1, 2] with traditional PLL units fails to ensure the proper phase control during its fast changes.

The technique for building the synchronous detectors using the PLL units of direct control at the rate of signal phase variation within the limits of bandwidth of detected signal frequencies was described in paper [3]. Such detectors [3, 4] make it possible to perform the synchronous detection at the expense of the adjustment of the received signal phase to the phase of high-stable reference generator. However these papers present the final results and do not reveal the specific requirements for choosing such method of PLL construction.

The purpose of this paper is to determine the complex transfer function (CTF) of phase filter and construct the functional diagram of PLL unit on the basis of this CTF.

Let the signal at the input of the unit of phase recovery of coherent carrier frequency (PRCC) has the waveform:

$$S_1(t) = A(t)\cos(\omega_0 t + \theta(t)), \tag{1}$$

where $A(t)$ is the amplitude of signal, $\omega_0$ is the carrier frequency, $t$ is time, $\theta(t)$ is the function of phase change of the carrier frequency during the signal passage through the communications channel (in the general case, a random function with the probability density distribution obeying the Rayleigh law [5]). Let us assume that the signal at the output of PRCC unit has the form:

$$\hat{S}_1(t) = kA(t)\cos(\omega_0 t), \tag{2}$$

where $k$ is a constant. Let us present these signals in symbolic form:

$$S_1(t) = \mathrm{Re}\, S_1(\mathrm{j}\omega) = \mathrm{Re}\left\{A(t)e^{\mathrm{j}[\omega_0 t + \theta(t)]}\right\}, \tag{3}$$

$$\hat{S}_1(t) = \mathrm{Re}\, \hat{S}_1(\mathrm{j}\omega) = \mathrm{Re}\left\{A(t)e^{\mathrm{j}[\omega_0 t]}\right\}. \tag{4}$$

Then according to the definition [6] the CTF for the PRCC unit can be written in the form: