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Simulating of Doppler radio signals at the receiving path of autonomous navigation systems for determining the speed of moving objects

By means of computer simulation, the influence of the processing of the receiving path of the navigation RTS on the structure of the signal reflected from a long object, which leads to the expansion of the spectrum of the reflected radio signal and the complication of measuring its Doppler frequency, was investigated. The adequacy of the simulation to the real observation of the signal and the possible influence on the characteristics of its contour and phase structure are analyzed.

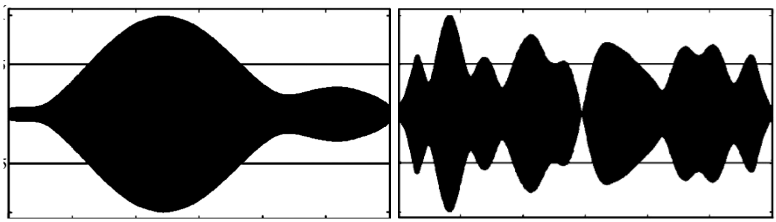
In work [1] the computer modelling of Doppler radio signals was carried out taking into account the influence of the secondary Doppler effect. The results obtained not only demonstrated their complex structure in the time and frequency domains, but also made it possible to identify in the fine structure of these signals natural changes in the envelope and carrier frequency caused by the influence of the secondary Doppler effect [2].

In passing, it should be noted that real Doppler signals can only be identified at the output of pre-processing and filtering devices. Therefore, in order to establish the adequacy of the models, obtained in works [1-2], to real Doppler signals, a necessary and obligatory condition is to simulate the passage of a mixture of input signal and noise through a narrowband filter. Obviously, the parameters of such a filter should correspond to the parameters of the frequency selective circuits used in the receiving and amplifying path and preceding the Doppler frequency measurement devices.

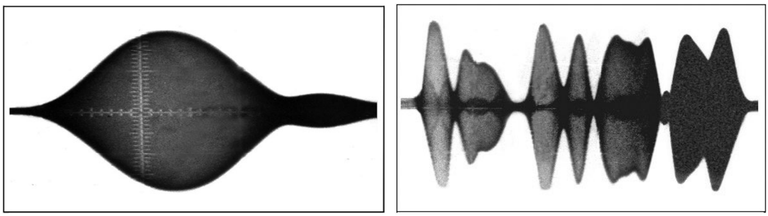
The bandwidth of the frequency selective circuits of the receiving path is determined by conflicting requirements: to provide maximum signal-to-noise ratio, the bandwidth should be minimal, and to reduce the duration of transients, the bandwidth should be wide. On the other hand, the bandwidth of frequency selective circuits should be selected taking into account the dynamic changes in the Doppler shifts of the frequency of the received radio signal, which correspond to the range of changes in the speed of the moving object.

The results of computer simulated and oscillograms of the real signal are shown in Figure 1.

Comparing the simulated signals (Fig. 1, *a*) with the oscillograms of real Doppler signals (Fig. 1, *b*), which were taken at a similar point of the receiving path, for the same or similar initial conditions, the obvious similarity of their shape and the same dependence of the nature of the envelope model and real signals on the speed of the moving object were revealed.



a



б

Fig. 1. Doppler radio signals:
a – the simulated signal at the filter output,
b – oscillogram of a real signal in the receiving path

To quantify the fluctuations of the carrier frequency of real and simulated signals, the data arrays obtained as a result of measuring the carrier frequency within short partial intervals, which were allocated during the existence of real and modelled radio signals, were processed. These data sets were used to analyse the distribution density curves, which gave grounds to accept the law of distribution of instantaneous frequencies as normal and to use the appropriate mathematical apparatus to estimate frequency fluctuations.

The results assessment of frequency fluctuations of computer simulated and real signal are shown in table. 1.

Table 1.

Assessment of frequency fluctuations of real and simulated radio signals

№ data array	$\sigma_{f\,\mathrm{sim}}$, *Гц*	$\sigma_{f\,\mathrm{real}}$, *Гц*
M1A	1,01	1,1
M1Б	0,84	1,2
M2Б	0,92	1,0
MC-16	0,81	0,9
MC-19	0,65	0,8
MC-20	0,73	0,85

Thus, a comparative analysis of the modelled and real signals showed their extreme closeness, which is the basis for confirming the adequacy of the proposed models [1-2]. From the point of view of improving the tactical and technical characteristics of Doppler autonomous navigation systems installed on moving objects, the simulation results can be used in the development of new and/or improvement of existing Doppler signal processing tools aimed at reducing the impact of noise and transients on the carrier frequency of these signals, as well as methods of measuring the carrier frequency in those fragments of the radio signal in which the Doppler frequency shifts are adequate to the speed of the moving object.

References

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