UDC 621.391.6:621.396.13 (045)

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UAV COMMUNICATION LINK DESIGN

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Abstract*—*This work represents component analysis of communication links of unmanned aerial vehicles. Defined main parameters of subsystems of transmitting and receiving paths. Performed the process of optimal design of the communication link using the system approach.

Index Terms—Communication link; transmission path; receive path.

I. INTRODUCTION

Unmanned aerial vehicles (UAVs) are not just a new class of aircraft, but a qualitatively new, higher level in military, as well as civil aviation. Work on the creation of the UAVs performed in connection with the constant increase of requirements to its flight characteristics. Comprehensive theoretical study of the UAV using a systems approach is very important as well as application of new models and algorithms for solving problematic issues that inevitably arise in the course of its design (Fig. 1).

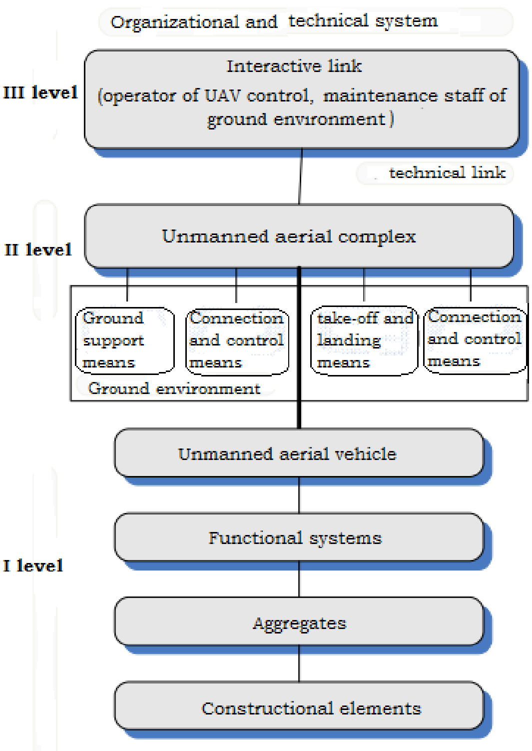

Fig. 1. Components of UAC

The structure of the scheme includes communications and control means [1]. It is a set of technical means designed to ensure the take-off, landing, UAV flight on a given profile and route in automatic or automatized modes and to control processes of on-board equipment application. The structure of the UAV on-board equipment includes a means of receipt and transmission of intelligence (monitoring) information. Such information can be delivered to consumers and taken after the UAV return on the place or relayed in flight on the ground control point ground (surface, air) control for improving the efficiency.

II. THEORETICAL INFORMATION

Command radio channel is designed for remote control of the UAV and provides:

– communication of UAV with ground control station (GCS);

– reception of UAV devices and payload control commands from GCS;

– transmitting telemetry data to the GCS;

– exchange using multiplexing CAN-channel.

Informational radio channel is designed for video transmission on the GCS (using video camera, thermal imager and so on).

The block diagram of the radio channel (Fig. 2) contains source of the messages, transmitter, transmitting antenna, transmission path of the electromagnetic wave energy with useful information, receiving antenna with the radio receiver. A feature of information transmitting via radio channel is the presence of sources of external disturbances.

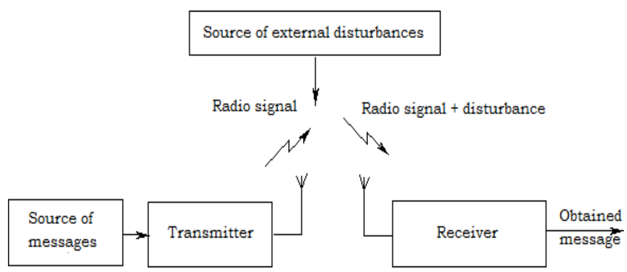

Fig. 2. Block diagram of the radio channel

A generalized block scheme of receiver and signals processing includes antenna, high frequency path, detector, low frequency path, actuator and the power supply.

Block diagram of receiver largely depends on the purpose and type of modulation (Fig. 3).

The high frequency path is designed for separation of oscillations with the frequency of the received signal and effective suppress on the other carrier frequency, in other words provides frequency selectivity signal [1].

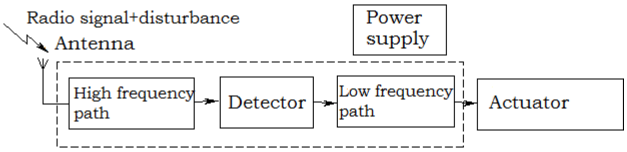

Fig. 3. Generalized block scheme of receiver and signals processing

Detector separates voltage corresponding to modulating signal, which is used to transmit useful message. Scheme realization of the detector depends on the type of modulation.

Path of low frequency is designed for the amplification of received signal to ensure proper operation of the actuator.

The main processing of the received signal is performed in the high-frequency path, detector and the low-frequency path. Schematic solution of radio receiver is determined by the common technical requirements (Fig. 4). Depending on the system performance of high-frequency path of radio receiver, there are two main types: straight receiver and superheterodyne receiver [2].

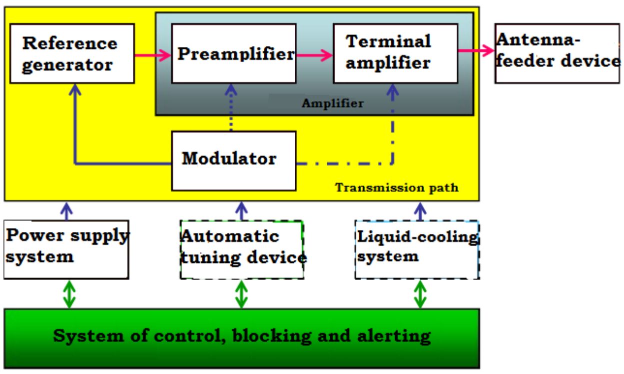

Fig. 4. Generalized structural scheme of radio transmitting device

III. Problem Statement

It is necessary to design communication link with the following characteristics.

1. Communication session time is not more than 10 minutes.
2. During the session it is necessary to transmit not less than 105 symbols on the information channel with the symbol error probability not more than 10^{-3}.
3. During the session it is necessary to measure range of activity with the error not more than 20 m with the prediction accuracy 50 km.
4. The energy potential (ratio of power of signal to noise spectral density) at the receiver input is 104 Hz.
5. Carrier frequency of communication link is 103 MHz.
6. Frequency range is not more than 0.5 MHz.

IV. Problem Solution

A. The noise band of phase-locked loop (PLL)

Suppose that 10 % of the session time (1 min) is given for the capture mode. Unknown frequency range is specified as 10^{-5} of the nominal value of 1 GHz, i.e. search should be conducted in the band $\Delta f_a = \pm 10$ kHz.

It is better to pass the range 5–6 times, so one pass will be performed during the time $T = 10$ s. Hence, we obtain the required speed of frequency agility, kHz/s:

$$\frac{\Delta f_a}{T_n} = 2$$

For reliable signal capture at this rate, PLL with quite low inertia (wide noise band) is required [3]. The noise band, Hz:

$$\frac{\Delta f_n}{f'} \geq 3 \frac{1}{\Delta f_n} \Rightarrow \Delta f_n = 80.$$

It is required to find the power of harmonic on the carrier frequency for the conditions of normal work of PLL in the capture mode.

Variance of noise error is determined by the formula:

$$\sigma_\varphi^2 \cong \frac{G_n \Delta f_n}{2P_{C'}},$$

where G_n is spectral density of the noise at the input of the PLL (W/Hz); P_C is harmonic power at the carrier frequency. Suppose $\sigma_\varphi^2 \leq 0.03$, then it is necessary to have:

$$\frac{P_c}{G_n} \geq \frac{\Delta f_n}{2\sigma_\varphi^2} = 1333,$$

where value is measured in hertz.

The problem statement specify the full energy potential of the radio channel is 104 Hz [4]. Consequently, it is necessary to give

$$\eta_C = \frac{1333}{10000} = 0.13$$

of the full signal power to the harmonic with the carrier frequency. The harmonic power on the carrier frequency is

$$\frac{1}{2}U_C^2\cos^2 m_C J_0^2(m).$$

The full power of signal PCM-PSK-FM is $P_C = \frac{U_c^2}{2}$ and, finally, $\eta_C = 0.13$.

B. Assessment of the required signal power in the information channel

There is 9 minutes for the receiving mode in the session. During this time, it is necessary to transmit 105 symbols. Hence, the duration of one symbol is $T_{RS}<540\cdot10^{-5}$ s. The information is transmitted by the third member of the signal spectrum [3]. Appropriate power is

$$P_{SI} = 2P_S\cos^2 m_S J_1^2(m_I) = P_S\eta_I,$$

where η_I is part of the power consumed for transmission of information. The probability of error does not exceed 10^{-3}, so (from the integral of probability, Hz): $\frac{P_{SI}}{G_{NI}} > 890.$

$$\frac{P_{SI}}{G_{NI}} = \frac{P_S}{G_N}\eta_I \Rightarrow \eta_I = \frac{890}{10^4}.$$

C. The choice of phase deviation in the phase modulator of transmitter

From the previous calculations, it is obvious that

$$\cos^2 m_S J_0^2(m_I) = 0.13,$$

$$\cos^2 m_S J_0^2(m_I) = 0.0445.$$

Solution of these transcendental equations shows that

$$m_S = 1.085, \quad m_I = 1,$$

where m is measured in radians.

D. Power distribution between signal components

The previous information shows that 0.13 of full signal power is taken for the carrier and 0.089 – for information. The power of signal synchronization could be found as

$$P_{SS} = P_S\sin^2 m_S J_0^2(m_I) = P_S\eta_S \Rightarrow \eta_S = 0,456,$$
$$\eta_S + \eta_I + \eta_C = 0,675.$$

It is necessary to choose the clock rate that provides given accuracy of measurement of activity range.

The range of activity is measured by the signal of symbol synchronization that has acute signal function. Maximal error of the activity range could be found as

$$\Delta R = \frac{c}{2}k^2\frac{2G_N}{\beta Q_0},$$

where c is the rate of radio wave propagation; $k^2 = 10$ is the coefficients of supply; $\beta = \frac{3}{\tau_I}$ is steepness of main pick slope of signal function; $Q_0 = P_{SS}T_M$ is the signal energy (time of measurement is 1 s). General error of range (20 m) is equally distributed between requested and answering radio link, so $\Delta R_{\max} = 10$ m. It can be found that $\tau_I < 4.4\cdot10^{-5}$ s. Therefore, clock rate must be less than value $\frac{1}{\tau_I} = 22.7$ kHz.

E. The choice of parameter of driving oscillator and pseudonoise signal generator

It is possible to find the required number of symbols in pseudonoise signal generator (n_{PS}):

$$n_{PS} = \frac{T_{PS}}{\tau_I} \geq \frac{0,0054}{4,4\cdot10^{-5}} = 122,7.$$

The nearest integer that satisfy this condition is 127. Recalculated value of impulse duration is 42.5 mcs and clock rate, kHz:

$$2F_{CL} = 23.53.$$

F. Testing of reliability of PLL work in the capture mode and carrier separation

Let's check about disturbance of signal harmonics that lie near the carrier. Phase-locked loop band is chosen with 80 Hz width and the range ± 10 kHz near the carrier is considered.

Frequency band, that is connected with modulation of carrier by signal PCM-PSK, lag on the frequency $4F_T = \pm47.06$ kHz.

Let's check if there can be a false capture of PLL by harmonic, associated with the modulation of the carrier by syncrosignal. They are located in the band of PLL and can be selected only by amplitude. The amplitude $A_{\max}$ is the largest that is in the search band:

$$A_{\max} = U_C\sin m_C J_0(m_C)\frac{1}{2}A_m,$$

$$A_m < \frac{4}{\pi\sqrt{n_{PS}}} = 0,113,$$

$$\sin m_C J_0(m_I) = 0,679,$$

$$A_{\max} < 0.038U_C,$$

where A_m is the maximum amplitude of the harmonic clock signal [4]. Useful harmonic has amplitude $0{,}362U_H$, i.e. it is in nearly 100 times larger in capacity, which allows easy selection.

G. Determination of the necessary bandwidth filters in the receive path

Expanded limiter must pass the signal PCM-PSK. In the spectrum of the signal $U(t)$ after the synchronous signal detector is located near the frequency of 47.06 kHz, i.e. $\frac{4...5}{T_{PS}}$ = 1 kHz. When the frequency instability 10^{-5} of the nominal frequency, shift does not exceed 500 Hz. Consequently, a bandpass limiter must be tuned to 47.06 kHz and have a bandwidth of about 1 kHz.

Assuming that the occupied frequency band corresponds to approximately $12F_T$, the necessary band filter as 142 kHz .

High-frequency transformer of receiving path should pass a sufficient number of useful components of the signal, i.e. have a band at least $\pm 12F_T$ plus instability of the carrier (±10 kHz). Consequently, the band should be 2(142 ± 10) = = 300 kHz. This quantity determines the line occupied by the radio channel frequency range.

V. CONCLUSIONS

Component analysis of communication links of unmanned aerial vehicles is carried out. Organizational and technical system of the unmanned aircraft complex is considered. Performed the process of optimal design of the unmanned aerial vehicles using the system approach. With the help of calculation following basic parameters of subsystems transmitting and receiving paths were chosen:

– frequency of driving oscillator in transmitting path;
– rate of transmitting of informational symbols;
– parameters of phase modulator of transmitter;
– parameters of PLL in receiver;
– bandwidth of band limiter.

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Received September 14, 2015

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В. М. Синєглазов, А. О. Кузьменко. Проектування радіоканала БПЛА

Розроблено компонентний аналіз радіоканала безпілотних літальних апаратів. Визначено головні параметри підсистем передавального і прийомного трактів. Запропоновано реалізацію процеса оптимального проектування радіоканала з використанням системного підходу.

Ключові слова: радіоканал; передавальний тракт; прийомний тракт.

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В. М. Синеглазов, А. А. Кузьменко. Проектирование радиоканала БПЛА

Разработан компонентный анализ радиоканала беспилотных летательных аппаратов. Определено главные параметры подсистем передающего и приемного трактов. Предложено реализацию процесса оптимального проектирования радиоканала с использованием системного подхода.

Ключевые слова: радиоканал; передающий тракт; приемный тракт.

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