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# Modeling of the Payload Signal Generator of the UAV Radio Transmitter based on the Phase Distortion Autocompensator

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**Abstract**:
A block diagram of a payload signal generator of a UAV radio transmitter with an autocompensator for phase distortion of a digital computational synthesizer with improved spectral characteristics compared to known solutions is considered. Schematic diagrams and circuit design models of the main paths of the shaper in the Micro-Cap environment with the analysis of the characteristics of the necessary radio elements and microcircuits have been developed. The simulation of the device operation in the frequency domain is carried out. Based on the simulation results, the conditions for selecting the parameters of the shaper to achieve the greatest compensation of phase distortions are formulated.

**Keywords**: unmanned aerial vehicle, signal generator, digital computing synthesizer, phase distortion auto-compensator.

## Introduction

The successful operation of unmanned aerial vehicles (UAVs) of various classes and fields of application requires the implementation of a reliable communication channel with the ground control complex [1,2].

The effectiveness of information exchange using UAVs mostly depends on the characteristics of radio transmitters and their signal generation systems to ensure reliable radio communication [3,4]. Optimization of the parameters of data transmission radio lines contributes to the growth of communication range and the quality of transmission of useful information due to the selection of the carrier frequency of data transmission, modulation methods, coding and other technical solutions. This requires, first of all, a high spectral purity of the signal generators of the UAV radio transmitters.

A promising way to improve the spectral characteristics of signal formers is the method of phase distortion autocompensation [5-9]. To implement this method, an autocompensator is added to the shaper circuit. A phase distortion signal is applied to one of the inputs of the autocompensator, a reference signal is applied to the other input. As a result of recording the phase difference between the distorted and the reference signal, a compensating signal is formed, which is used to suppress phase distortion.

The aim of the work is to model and analyze the circuit of the signal generator of the payload of the UAV radio transmitter in order to achieve the best degree of phase distortion compensation.

## Quadrature signal generator of a UAV radio transmitter based on a digital computing synthesizer (DDS)

The disadvantage of the quadrature signal generator of the UAV payload radio transmitter is the low spectral purity of the synthesized signals due to discrete side spectral components and the noise part of the DDS spectrum [10-14]. To improve the spectral characteristics of the shapers, it is promising to use a phase distortion autocompensation device of the DDS. The block diagram of the payload signal generator of the UAV radio transmitter with an autocompensator of phase distortion is shown in Fig. 1.

The standard quadrature shaper without autocompensation includes the following blocks: CG - clock generator, FM1 and FM2 – frequency multipliers, DDS - digital computing synthesizer, LPF1 and LPF2 - low–pass filters of quadrature outputs of DDS, QM – quadrature modulator. A control device consisting of two controlled phase shifters (CPS1 and CPS2) and a 90-degree phase shifter is used to compensate for each quadrature signal of the DDS.

The clock signal has the form of a meander, the output signal of the digital-to–analog converter (DAC) of the DDS has a stepped form. Signal processing in the reference and information path allows you to align their shapes and amplitudes while maintaining phase shifts. The structure of the reference path includes a trigger Tr1, the information path includes a differentiating circuit (DC), amplifiers (A1 and A2), a full-wave rectifier (FWR) and a second trigger Tr2. The control path generates a signal, which is subsequently used in antiphase to compensate for phase distor-

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tions. The structure of the control path includes a phase detector (PD), a low-pass filter and an A3 amplifier.

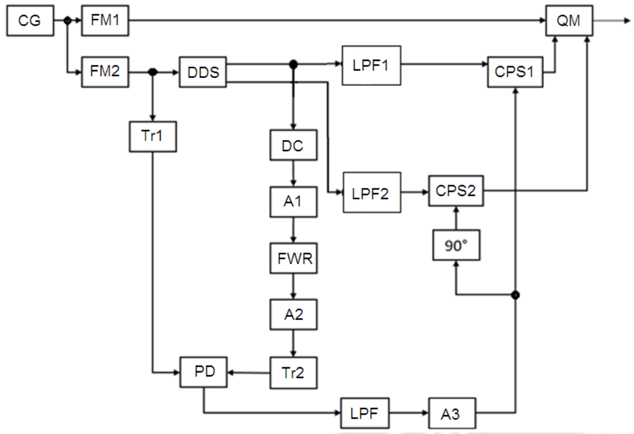


Figure 1 - The circuit of the payload signal generator of the UAV radio transmitter with a phase distortion autocompensator

**Circuit design of the signal generator**

We will carry out the sequential development of circuit diagrams of the paths of the signal generator and their circuit models.

DDS output signal model

In [13, 14], a mathematical model of the output signal of the DDS is given, taking into account both errors that occur when the phase code is truncated and errors associated with quantization of the amplitude

$$s[i] = \frac{trunc\left( N \cdot \sin\left( 2\pi \frac{2^b}{2^p} trunc\left[ \frac{K}{2^{p-a}} i \right] \right) \right)}{N}$$

where $trunc(x)$ is the integer part of the number $x$, $N = 2^n$ is the number of DAC quantization levels, $n$ is the DAC bit length, $a$ is the ROM bit length, $K = round\left( \frac{f_{ЦВС} M}{f_T} \right)$ is the synthesized frequency code, $round(x)$ is the nearest integer, $M = 2^p$ is the number of phase accumulator counts, $p$ is the phase accumulator bit length, $i = 0 \ldots M-1$, $b = p - a$ is the number of rounding bits.

Information path model

Figure 2 shows a schematic model of the information path of the phase distortion compensator of the DDS, implemented in the Micro-Cap program [16, 17].

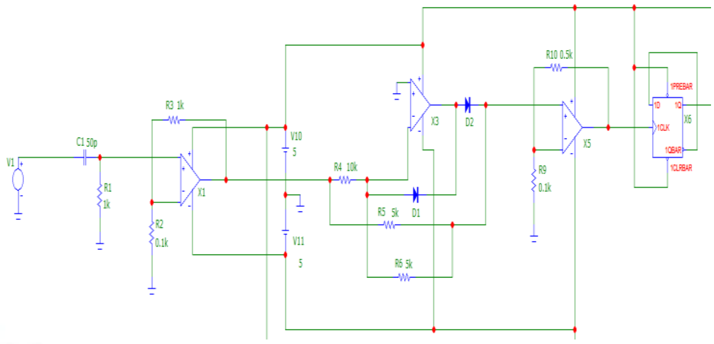

Figure 2 – Schematic model of the information path of the DDS phase distortion autocompensator

The schematic diagram of the DC differentiating circuit is a first-order high-pass filter (HFF) with a capacitor C1 of 50 pF and a 1 kOhm resistor with a cutoff frequency configured to pass the required clock frequency.

The schematic diagram of the amplifier A1, with a resistor R2 in 0.1 kOhm and R3 in 1 kOhm is implemented on the operational amplifier AD8055. This single-channel voltage feedback amplifier has a wide frequency band (300 MHz), small errors of differential gain and differential phase, low current consumption, the possibility of a 12 V unipolar power supply, a current load capacity of more than 60 mA. These advantages make the AD8055 an ideal choice for portable equipment and battery-powered devices in which power consumption and dimensions are especially important.

Schematic diagram of a full-wave rectifier on one AD8055 operational amplifier, diodes D1 and D2, BAS 16L model with high switching speed (less than 4 ns). T-triggers are implemented on the basis of the 74HC74 chip.

Model of the control path

The implementation of the phase detector of the control path is based on the logic element “Exclusive OR" on the 74HC86 chip. The low-pass filter LPF2 is a first–order RC filter with the ratings of the capacitor C3 5nF and the resistor R11 - 1 kOhm. The amplifiers are implemented as a model of an ideal link with a resistor R12 with a resistance of 0.1 kOhm and R13 at 0.2 kOhm.

Figure 3 shows a model of the control path.

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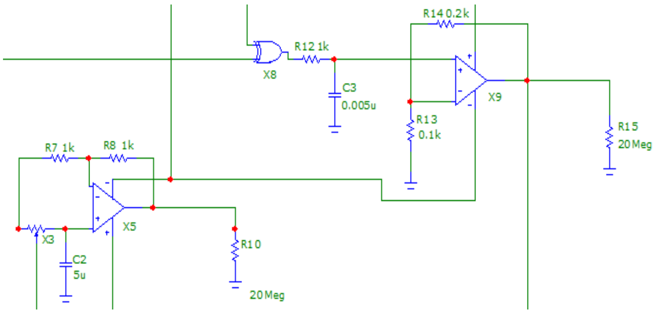


Figure 3–The resulting model of the control path phase distortion autocompensator DDS

**Simulation of the operation of the signal generator**

Using the obtained model of the phase distortion autocompensator of the payload signal generator of the UAV radio transmitter, we conduct its simulation. We take into account the real parameters of the DDS for three different output frequencies: 3 MHz, 8 MHz and 12 MHz.

Figure 4 shows the spectrograms of the DDS output signal at an output frequency of 3 MHz when the conditions of full compensation are met, with a deviation of 25% from these conditions, with a deviation of 50% from these conditions, with a deviation of 75% from these conditions and with an open autocompensation loop, Figure 5 - with an output the frequency of the DDS at 8 MHz, and in Figure 6 - at the output frequency of the DDS at 12 MHz.

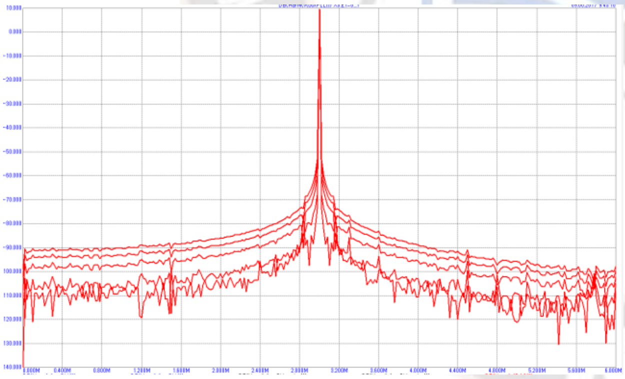

Figure 4 - Spectrograms of the DDS output signal at a frequency of 3 MHz with various A3 gains

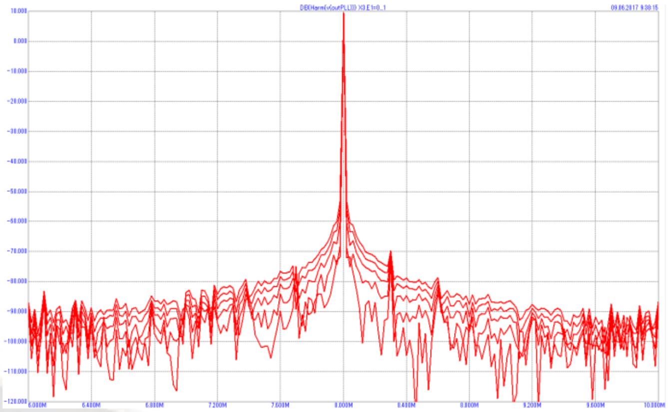

Figure 5 - Spectrograms of the DDS output signal at a frequency of 8 MHz at various A3 gains

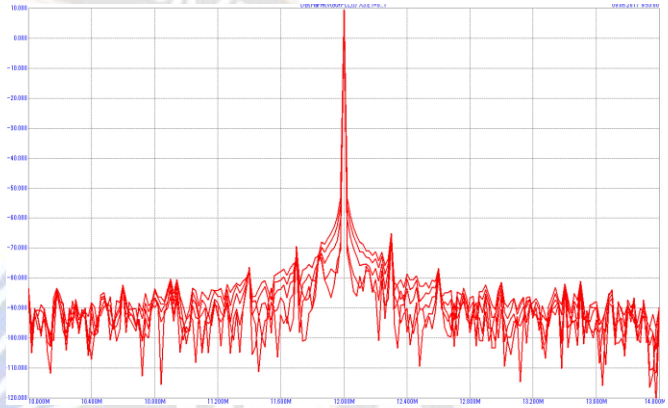

Figure 6 - Spectrograms of the DDS output signal at a frequency of 12 MHz at various A3 gains

**Conclusion**

A block diagram of a payload signal generator of a UAV radio transmitter with an autocompensator of phase distortions of a digital computational synthesizer is considered. Schematic diagrams and circuit models of the main paths of the phase distortion autocompensator of the digital computational synthesizer in the Micro-Cap circuit modeling program have been developed, taking into account the selection of the necessary radio elements and microcircuits, analysis of their technical characteristics and advantages, and the resulting model of this device has been obtained. A simulation of the operation of the device in the frequency domain was carried out, as a result of the simulation, spectrograms of the output signal of the DDS were calculated at various output frequencies and gain coefficients of the control path amplifier A3. Based on the simulation results, the conditions for selecting the parameters of the shaper to achieve the greatest compensation of phase distortions are formulated.

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