INTERNATIONAL SCIENTIFIC CONFERENCE
20-22 November 2025, GABROVO

DESIGN OF THE RADIO SIGNAL POWER AMPLIFIER FOR COMMUNICATION SYSTEMS FOR CONTROLLING UNMANNED MOBILE OBJECTS WITH INTENTIONAL AMPLITUDE AND PHASE DISTORTIONS

Ruslan Antypenko[1], Mikhailo Prokofiev[2]

[1] Igor Sikorsky Kyiv Polytechnic Institute, Kyiv, Ukraine
[2] Vasyl Stus Donetsk National University, Vinnytsia, Ukraine

Abstract
A solution to the problem of forming and amplifying the radio signal with the possibility of special intentional influence on linear signal distortions (amplitude and phase) in the transmission path of the unmanned mobile object control system is considered. The results of designing the power amplifier for radio signals in the decimeter wave range with high efficiency based on inexpensive LDMOS (Lateral Diffused Metal-Oxide Semiconductor) transistors manufactured by Ampleon Netherlands B.V. are presented. Nonlinear transistor models and the Load Pull method were used in the design. Such low-cost amplifiers are capable to operate in difficult conditions, having small dimensions, resistance to overloads, protection against overheating and damage to antenna systems. The possibility of changing the parameters of the frequency response of the transmission path in a wide range is provided.
Keywords: unmanned moving objects; communication system; power amplifier; LDMOS; electronic warfare.

INTRODUCTION

In publications [1, 2] it is shown that linear distortions of signals transmitted in communication paths, particulary in control systems for unmanned mobile objects, are caused by non-ideality of frequency characteristics of individual sections of such paths. Variants for solving the problem of special intentional influence on linear (amplitude and phase) distortions of signals in communication paths of such systems to influence the degree of deterioration of the signal/interference ratio are also considered and, as a result of this the deterioration of the probability (range) of detecting such signals during correlation reception. This publication considers the peculiarities of the functioning of the communication system for control of unmanned mobile objects and shows the results of designing the radio signal power amplifier for this type of system.

COMMUNICATION SYSTEM FOR CONTROLLING UNMANNED MOBILE OBJECTS

The problem of creating effective interference to distort signals transmitted in the communication paths of unmanned mobile object control systems in real time is still relevant. The main goal in selecting signals from unmanned mobile objects is to achieve high resolution under real-world limitations caused by the influence of a wide range of external interference, deviations in the formation of amplitude and phase-frequency characteristics (AFR and PFR) of the receiving and transmitting path of communication systems.

The mathematical solution [1] of the above problem is proposed by creating interference that reduces the probability of detecting signals in communication channels during correlation reception. The solution is based on the creation in the system of distortions of the time interval between the

doi: www.doi.org/10.70456/.........................

distorted and undistorted reference signals in Hilbert space. Linear signal distortions in the signal reception path are due to the unevenness of the frequency response and the nonlinearity of the phase response.

Calculations show that for a signal with the uniform spectrum at the constant frequency response, the root-mean-square nonlinearity of the phase response of about 0.5 radians can lead to the deterioration of the signal/interference ratio by 12.5% [2].

This fact is important for receivers of systems with branched antenna systems which track the direction to the control object using the phase method of determining the range.

Hiding the geographical coordinates for control systems can be implemented by adjusting the delay time of the tracking signals by means of appropriate periodic adjustment of the frequency characteristics of their receiving and transmitting paths by the third-party surveillance systems.

If the parameters of the frequency characteristics, additionally installed in the transmitter and receiver of the control system of the amplitude and phase distortion simulators, are periodically changed, then for third-party reconnaissance surveillance systems that estimate the geographical position of the control system by time T, conditions are created for disinformation about the true location of the control system for unmanned moving objects.

The signal delay time τ can be changed by increasing or decreasing both the magnitude of the phase cutoff and the magnitude of the nonlinearity of the phase-frequency characteristic. Each of such changes must be reflected in the amplitude and phase distortion simulators, that is, the frequency response and phase-frequency response of the simulators must be adjusted in accordance with these changes.

One of the main components in such systems is the high-frequency radio signal power amplifier, which meet the requirements for low cost, small dimensions, resistance to overloads, the presence of protection against excess ambient temperatures and damage to antenna systems.

POWER AMPLIFIER STRUCTURE

The amplifier with the output power of at least 100 W for the frequency range 700 MHz – 840 MHz is designed, provided that at the nominal input signal power of 0 dBm the gain must be at least 50 dB.

The structure of the designed power amplifier is shown in Fig. 1. Based on the given characteristics, it has a three-stage structure.

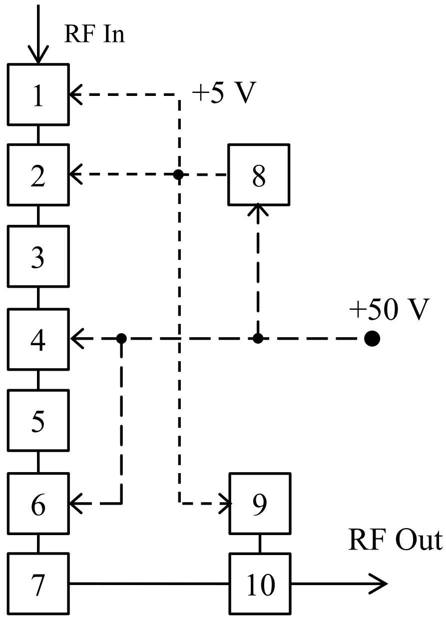

***Fig. 1.** Amplifier block diagram*

The input signal is given to the attenuator and phase shifter 1 with electronic control. This allows to create intentional linear distortions of the signal in accordance with the system operation algorithm. The amplifier control system in Fig. 1 is not shown. From the output of the attenuator, the signal is given to the input of the first amplification stage 2. As the active element, the linear low-noise integrated high-frequency amplifier GVA-63+ manufactured by Mini-Circuits [3] in the SOT-89 package with the supply voltage of 5V was selected. The input and output of this amplifier are matched to the characteristic

"UNITECH – SELECTED PAPERS" vol. 2025
Published by Technical University of Gabrovo
ISSN 2603-378X

doi: www.doi.org/10.70456/.........................

impedance of 50 Ohms. The gain coefficient in the given frequency range is not less than 21 dB, and the output power at 1 dB compression (P1dB) is 19 dBm.

As active elements of the second 4 and third 6 stages, inexpensive LDMOS transistors in the plastic case manufactured by Ampleon Netherlands B.V. [4] were selected. For the second stage 4, the BLP15H9S10 transistor is used, and for the third output stage, the BLP15H9S100 transistor, accordingly. Both transistors have the frequency range from HF to 2 GHz, and their nominal supply voltage is 50 V.

The BLP15H9S10 transistor in the given frequency range has the gain of about 22 dB and an output power of 10 W. Accordingly, the BLP15H9S100 transistor has the gain of 20 dB and an output power of 100 W.

The fact that both transistors should have the same supply voltage was one of the important factors that had influenced on their choice, since this greatly simplifies the amplifier power supply system. They are also characterized by the excellent ruggedness. Other characteristics of the transistors are available on the Ampleon Netherlands B.V. website [4].

The structural block 3 in Fig. 1 describes the scheme of matching the 50 Ohm resistance with the input impedance of the LDMOS transistor 4. Block 5 provides matching of the output impedance of the transistor 4 with the input impedance of the transistor 6. Block 7 provides matching of the output impedance of the transistor 6 with the 50 Ohm impedance.

Despite the significant resistance of the BLP15H9S100 transistor to high Voltage Standing Wave Ratio (VSWR) load, the amplifier structure provides a circuit to protect the amplifier from damage to the antenna systems. This subsystem includes the directional coupler 10 and the VSWR measurement circuit 9 based on the ADL5519 integrated circuit, manufactured by Analog Devices [5]. When the measured VSWR value reaches the predetermined threshold value, the amplifier is turned off. Usually, if the VSWR of the antenna systems exceeds 2…2.5, this indicates their damage.

To power the input attenuator 1, the first amplification stage 2, and the VSWR measurement circuit, the amplifier structure in Fig. 1 includes a step-down DC/DC converter with an output voltage of 5V.

CALCULATION OF COORDINATION SCHEMES

One of the features of the developed amplifier is the structure of the interstage matching circuit 5 (Fig. 1). The typical structure of the matching circuit for the two-stage amplifier is shown in Fig. 2.

In the diagram of Fig. 2, the LDMOS transistor of the first stage is designated as 2, and the LDMOS transistor of the second output stage is designated as 5. The 1st is the matching circuit of the 50 Ohm impedance with the input impedance of transistor 2. Block 3 denotes the matching circuit of the output impedance of transistor 3 with the 50 Ohm load.

Accordingly, for the second stage, block 4 denotes the matching circuit of the 50 Ohm impedance with the input impedance of transistor 5, and block 6 denotes the matching circuit of the output impedance of transistor 5 with the 50 Ohm load resistance. Transistors 2 and 5 are independently optimized for operation with the signal source and the load with the 50 Ohm impedance. This scheme is often used in practice because it is relatively simple to calculate and set up. In this work, the alternative matching method [6] was used, which is illustrated in the amplifier structure Fig. 1. In this case, the output impedance of the LDMOS transistor 4 is matched directly to the input impedance of the LDMOS transistor 6 without transformation to the value of 50 Ohm. The Cadence AWR Design Environment Platform was used to design the power amplifier. The transistor models provided by the manufacturer Ampleon Netherlands B.V. were used to perform the calculations.

ISSN 2603-378X

doi: www.doi.org/10.70456/.........................

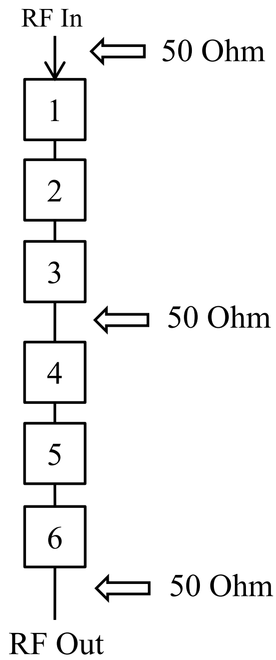

Fig. 2. *Typical structure of the two-stage amplifier matching circuit*

Load-Pull Analysis [7] was used to perform the calculations using the Network Synthesis tool. This method allows finding the optimal resistance to achieve maximum power, gain or the lowest distortion, which is important for achieving the specified characteristics during the design of the amplifier. The geometric dimensions of the matching circuits were additionally specified by EM modeling in AXIEM, which is the component of The Cadence AWR Design Environment Platform.

The simulation results are shown in Fig. 3 - Fig. 5. All figures are drawn without scale. The connection of the capacitors to GND is conditionally not shown. The circuit elements are made on the basis of the microstrip line with the dielectric base RO4350B manufactured by Rogers Corporation [8] with the thickness of 30 mils. The shape of the matching circuits is due to the necessity to place the power amplifier in the limited volume with the dimensions of the printed circuit board not exceeding 100x100 mm. The calculated input microstrip matching circuit (block 3 in Fig. 1) is shown in Fig. 3.

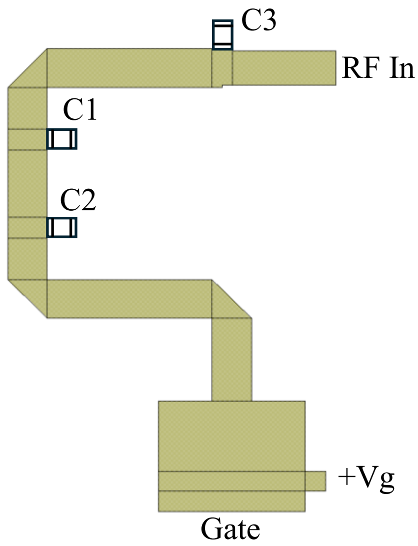

Fig. 3. *Input microstrip matching circuit (block 3 in Fig. 1.)*

This circuit allows you to match the signal source with the output impedance of 50 Ohms with the input impedance of the BLP15H9S10 transistor (block 4 in Fig. 1) and provides the bias voltage to the gate of the transistor. The topology of the inter-stage matching circuit (block 5 in Fig. 1), which implements the matching of the output impedance of the BLP15H9S10 with the input impedance of the BLP15H9S100, is shown in Fig. 4.

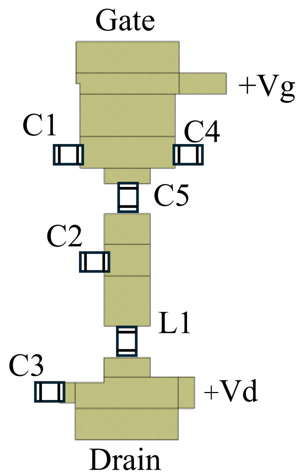

Fig. 4. *Inter-stage microstrip matching circuit (block 5 in Fig. 1.)*

It also provides voltage supply to the gate and drain of the transistors and implements electrical isolation between these circuits.

doi: www.doi.org/10.70456/..........................

The calculated output microstrip matching circuit (block 7 in Fig. 1) of the BLP15H9S100 transistor with the 50 Ohm load is shown in Fig. 5. In addition to the resistance transformation, the circuit additionally provides voltage supply to the drain of the transistor.

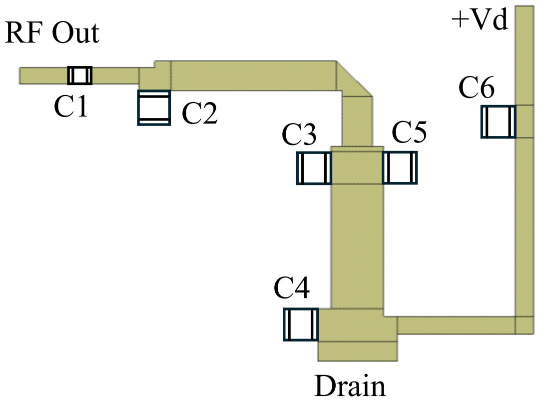

Fig. 5. *Output microstrip matching circuit (block 7 in Fig. 1.)*

Each amplifier stage was also analyzed for stability using The Cadence AWR Design Environment Platform. The two-stage final power amplifier manufactured according to the design results had coefficient gain of at least 40 dB in the 700 MHz - 840 MHz band. The maximum end-to-end gain of the entire three-stage amplifier exceeds 60 dB and is adjustable within -30 dB thanks to the input attenuator (block 1 in Fig. 1). The saturation power of the entire three-stage amplifier was at least 110 W, and the PAE in the operating frequency range was at least 65%.

CONCLUSION

The implementation of the function of intentional additional creation of amplitude and phase distortions during the reception and transmission of signals was taken into account when building the optimal receiver for the control system for unmanned mobile objects and can be effectively used to misinform third-party receiving devices in order to hide the exact coordinates of the control systems for unmanned mobile objects. Calculations show that changing the mean square nonlinearity of the phase-frequency characteristic allows to cause an increase in the uncertainty of the coordinates of the moving object by 12.5%.

To solve the problems set, it is necessary to provide for the possibility of changing the parameters of the phase-frequency characteristics of the transmitting devices in a wide frequency range

For such systems, the design of power amplifiers with the combination of different methods gives good results. In particular, the designed three-stage power amplifier based on LDMOS transistors with low cost is capable of operating in difficult conditions, has small dimensions, resistance to overloads, protection against overheating and damage to antenna systems, as well as the ability to adjust the phase and gain within significant limits.

REFERENCE

[1] Оцінка впливу зовнішніх спотворень у системах зв’язку на ймовірність правильного виявлення сигналу. Антипенко Р.В., Гресь О.В., Дворський В.Я., Крижановський В.Г., Прокофьєв М.І., Physical and Technological Problems of Transmission, Processing, PREDT-2025). c.161-162

[2] Железаров І., Ілларіонов Р., Прокофьев М., Дворський В. Оцінка лінійних спотворень у телекомунікаційних лініях// Реєстрація, зберігання і обробка даних. 2021. Том 23. № 4. – с. 28-36.

[3] Mini-Circuits. https://www.minicircuits.com/

[4] Ampleon Netherlands B.V. https://www.ampleon.com/

[5] ANALOG DEVICES https://www.analog.com/en/index.html

[6] Raghuvir Tomar, Prakash Bhartia. A Simple Interstage Matching Technique for Designing Hybrid Microwave Power Amplifiers// IEEE microwave magazine, September 2003, p. 67 - 84

[7] Load-Pull Analysis for Optimizing PA Performance// White Paper. Cadence Design Systems, Inc.

[8] Rogers Corporation https://rogerscorp.com/

doi: www.doi.org/10.70456/.........................