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AMATEUR LOW POWER RADIO FREQUENCY COMMUNICATION DEVICE FOR FM RANGE

The article is devoted to developing a radio frequency communication device as an amateur radio station. A radio frequency communication device is a basic element of wireless systems. It has become widely used in general-purpose and special-purpose wireless communication systems. Portable radio frequency communication devices are used in radio waves' meter and decimeter range. Such devices have a simple electrical circuit and a simple design. Therefore, developing new electrical circuits and creating new designs of radio frequency communication devices attract considerable attention from researchers. A large number of publications are known. These publications comprehensively examine the parameters and characteristics of RF communication devices for special-purpose systems. Less attention has been paid to developing and researching amateur radio frequency communication devices. The paper analyzes various operating conditions of radio stations and their influence on the power and frequency range of the radio signal. An analog of the radio communication device was studied, and its electrical schematic diagram was considered. The paper proposed a new electrical circuit of the transmitter for the radio frequency communication device, created an experimental model of the device, and experimentally investigated its parameters and characteristics. The article presents a structural diagram of a radio frequency communication device, electrical diagrams of a radio frequency communication transmitter unit, a low-frequency amplifier, a modulating generator, and a power amplifier cascade. The transmitting part of the device operates at a frequency of 103.351 MHz, and the amplitude of the transmitter's output signal is 1.5 V. The radio signal generated by the device has frequency modulation and low power. As a result of experimental studies, graphical dependences of the output signal amplitude, current consumption, and transmitter power on the load resistance were constructed.

Key words: *radio-frequency station, intercoms, radio-frequency transmission, communication range, autonomy of work.*

Formulation of the problem. In various operating conditions (depending on the level of electromagnetic interference, terrain relief, and presence of obstacles such as urban buildings or trees), there are radio stations of different power levels and frequency ranges.

It may seem that staying connected today is very simple and easy. Mobile phones and smartphones have become affordable and compact, thus gaining wide usage. However, it is important to remember that your phone can only exist with a mobile operator's base station [1].

Modern people spend a significant amount of time communicating through mobile phones, but only a few understand how they work and how they affect our bodies. For example, the harmful radiation from a mobile phone [2, 3] compared to a two-way radio device: 2 GHz and 0.5 W versus 0.1 GHz and 0.02 W.

Additionally, professional radio stations and two-way communication devices can be expensive, which can be a problem for consumers with limited budgets who need help to afford such equipment. Therefore, it has been decided to develop a low-budget radio communication device that will be cost-effective and efficient over distances equivalent to professional radio communication tools. This device will be utilized in areas where mobile communication systems provide no radio coverage.

Analysis of recent research and publications. An analog communication device was chosen for its simplicity, resembling popular Chinese toy radios based on transistors. The electrical schematic diagram of such a device is depicted in Figure 1 [4].

The receiving section is built around the microchip A1 KXA058, commonly used for pocket-sized UHF-FM receivers. The receiving section is tuned to a frequency of 40 MHz, which is widely used for wireless telephones. Switching between receiving and transmitting modes, as well as turning off the device, is controlled by toggle switch S1, which has a middle position (the device is off in the middle position).

The signal from the antenna is directly fed to the RF section A1 without using an input circuit. The heterodyne circuit formed by L1-C16 determines the tuning frequency. The low-frequency voltage from the output of A1 is then fed to a simple single-stage amplifier using VT1, loaded with a compact speaker B1.

The transmitter is designed based on a well-known circuit used in radio microphones, but it is slightly more powerful (10 mW). The VT2 transistor serves as a high-frequency generator, and the generation frequency depends on the circuit's parameters formed by coil L4 and capacitor C9.

The oscillation circuit (C9-L4) is tuned to a frequency of 40 MHz, corresponding to tuning the receiving sections of other devices within the intercom system.

The loaded transistor is connected to inductor L5, where the RF voltage is generated and delivered to the antenna through a Pi-like filter consisting of capacitors C12-C13-L6-C14-C15.

To achieve frequency modulation, varactor diodes VD1 and VD2 are used, which, together with capacitor C8, create additional capacitance in the transmitter circuit and change its frequency [5]. The low-frequency voltage for the varactor diodes is obtained from the output of the single-stage audio frequency amplifier using transistor VT3, with an electret microphone M1 connected to its input.

During the adjustment of the transmitter, it is important to ensure that the emitted power does not exceed 10 mW (the permissible value for such devices) [6]. The power output depends on the resistance ratio of R7, R8, the power of transistor VT2, and the voltage of the power supply source.

The analog device is designed to provide two-way communication within a range of 100–500 meters, depending on the terrain and electromagnetic environment. The electrical schematic shows that a 9V power supply powers it.

Comparing the designed communication device with the analog device, it can be noted that it will have a greater communication range by increasing the power supply voltage, which can reach up to 12V. Additionally, the device will maintain its functionality at 5V, and the operating range directly depends on the power supply voltage.

Problem statement. This work aims to develop a new radio communication device for use within an amateur radio station.

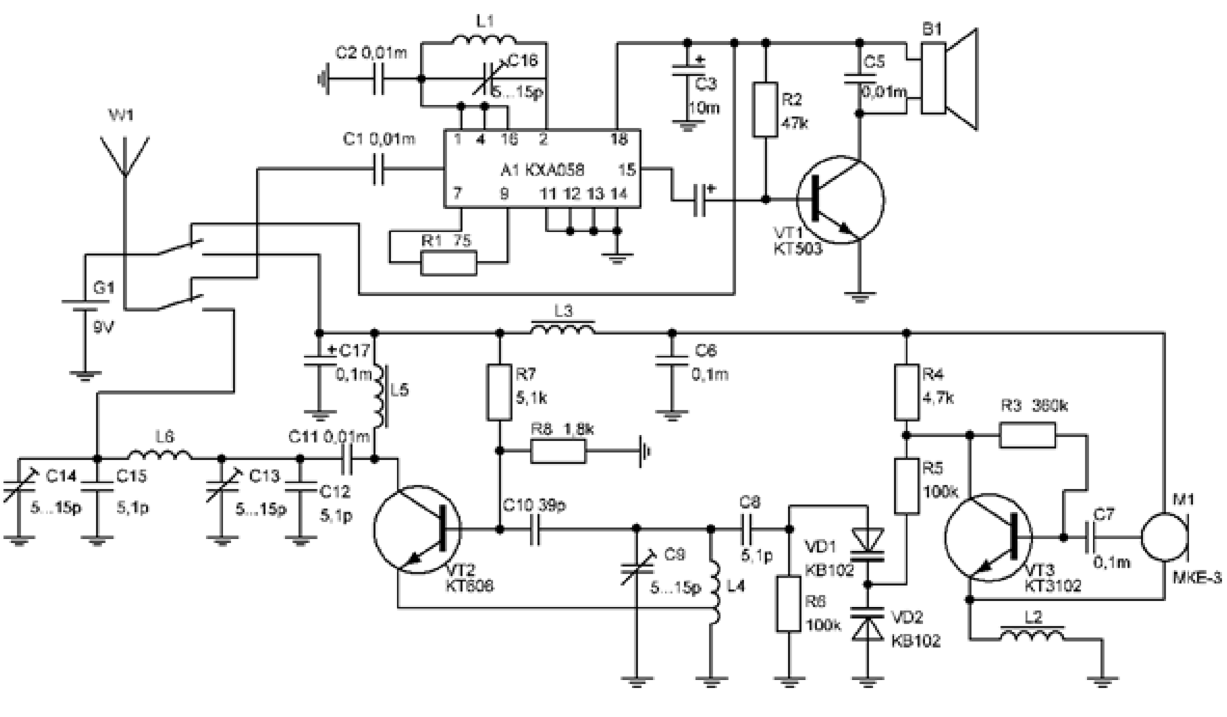


Fig. 1. Electrical schematic diagram of the analog communication device [4]

To achieve this goal, the following tasks need to be accomplished:

1. Conduct electrical calculations for the transmitter circuits of the radio communication device;
2. Create a prototype of the radio communication device;
3. Experimentally investigate the parameters and characteristics of the radio communication device.

Exposition of the main material

The structure scheme of the radio communication device is provided in Figure 2.

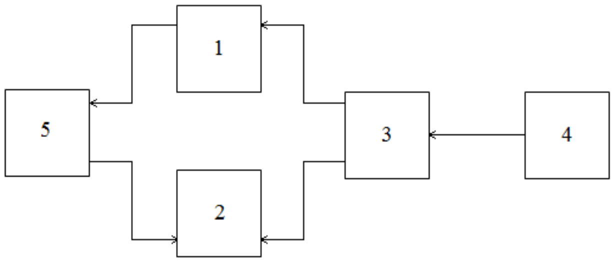


Fig. 2. Structural diagram of the radio communication device: 1 – transmitter unit; 2 – receiver unit; 3 – switches; 4 – power supply; 5 – antenna

A structural diagram of the transmitter unit of the radio communication device is shown in Figure 3.

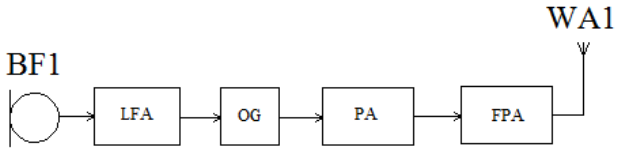


Fig. 3. Structural diagram of the transmitting device

The connection diagram of the microphone (BF1) is classic and is shown in Figure 4. The electret microphone in this circuit can be represented as a resistor whose resistance varies by the sound signal, influenced mechanically by the diaphragm. With resistor R1, the microphone forms a voltage divider with the power supply. As the resistance of the microphone changes, the portion of the DC power supply voltage distributed across the microphone also changes.

The voltage at point "A" varies synchronously with the sound signal received by the microphone. The signal for further processing is taken from the positive contact of the microphone (point "A"). Capacitor C1 allows only the AC voltage to pass through while blocking the DC current, resulting in a clean AC signal being obtained at point "B". In other words, the capacitor blocks the DC voltage but responds to the rapid changes in this voltage, changing accordingly in sync with the sound signal.

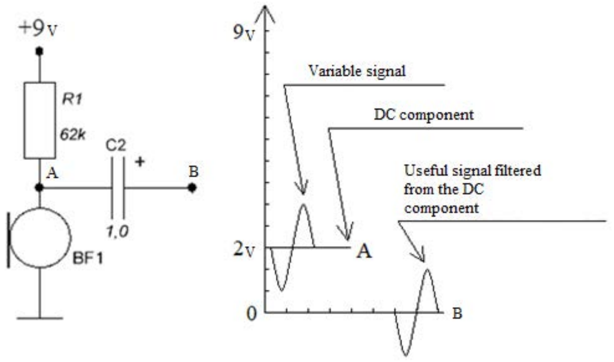


Fig. 4. Microphone connection diagram and processes occurring in the microphone circuit

The low-frequency amplifier is designed to amplify the signal level received from the microphone [7]. The electrical circuit of the amplifier, built in a common emitter configuration, is shown in Figure 5 [7]. A load of transistor VT1 is resistor R3.

The next stage is the oscillator circuit. Its electrical circuit is shown in Figure 6. The oscillator circuit is responsible for generating a reference signal with specified frequency parameters, which is used to form the carrier wave at the output of the transmitter. FM modulation is achieved in the oscillator circuit through frequency deviation by changing the operating point of the transistor.

These stages in the microphone circuit and subsequent amplification and modulation stages play crucial roles in capturing, processing, and transmitting the audio signals in the radio communication device.

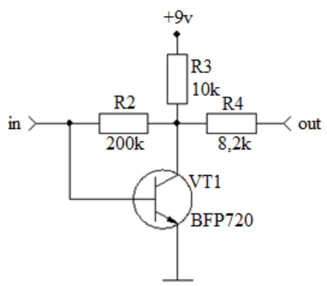


Fig. 5. Circuit diagram of the low-frequency amplifier [7]

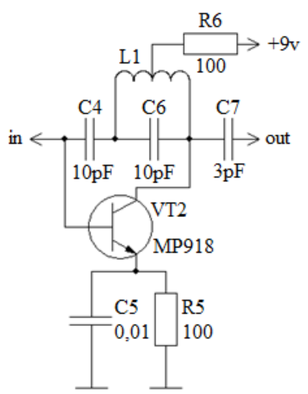


Fig. 6. Circuit diagram of the modulating oscillator

The main component of the power amplifier (Fig. 7) is the transistor VT3. The final power amplifier is constructed using transistor VT4. Together, these amplifiers perform the amplification of the radio signal.

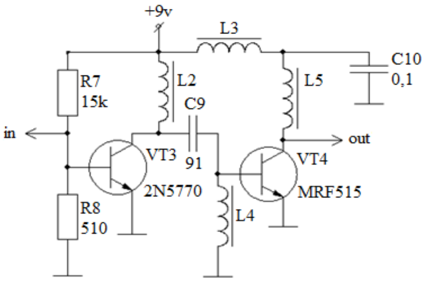


Fig. 7. Circuit diagram of the power amplifier

For the receiver section of the device, the "MANBO S-202" FM receiver [8] was selected, the external appearance of which is shown in Figure 8.

Fig. 8. FM Receiver MANBO S-202

Front-tuning knob (88-108 MHz) and volume control (Vol). Manbo S-202 is based on the CXA1538S microchip [9] in a planar package. The IF amplifier is implemented using the TDA7050. The RF coils are frameless, and the IF filter is piezoelectric. The assembly is done on a single-sided printed circuit board. The tuning capacitor is a dual-film type (with film pieces placed between the plates). It requires a 3V power supply. The schematic of the FM receiver MANBO S-202 is shown in Figure 9.

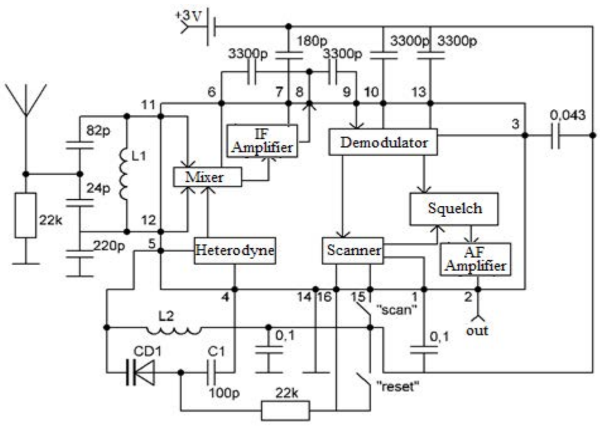


Fig. 9. Schematic diagram of the FM receiver MANBO S-202 [9]

The CXA1538S is designed for FM stereo/AM radio receivers. It includes an FM/AM front-end, FM/AM IF amplifier, FM/AM output signal, and FM stereo output demodulator. The block diagram of the microchip is shown in Figure 10.

Results of experimental investigations

For experimental investigations, a test bench consisting of the following units was used:

1. Power supply unit BP-30;
2. Oscilloscope SDS 1202-X E;
3. Low-frequency generator G3-36.

A photo of the test bench is shown in Figure 11.

The structural diagram of the test bench is shown in Figure 12.

The microphone was shorted using a jumper to investigate the signal shape at the transmitter output, and an equivalent antenna was connected to the transmitter output. The experimental results are shown in Figure 13(a).

As seen in Figure 13(a), the tuning frequency of the transmitter is 103.351 MHz. Measurements were made to investigate the relationship between the amplitude value of the output signal and the load resistance. For this purpose, a short circuit was made at the microphone, and an equivalent antenna was added. The equivalent antenna includes a variable resistor up to 1 kΩ. By changing the resistance of this resistor, we investigated the dependence of the output signal amplitude on the load resistance. Photos of the experimental research results are shown in Figures 13(b) and 13(c). The experimental results of the dependence of the output signal amplitude on the load resistance are presented in Table 1.

Table 1

Values of the dependence of the output signal amplitude on the load resistance

U_m, V	2,8	2,2	1,45	0,85	0,55
R_{load}, Ohm	1000	200	91	41,5	5,1

Figure 14(a) shows the plot of the dependence of the signal amplitude at the output on the load resistance.

In the study, we also conducted measurements of the dependence of transmitter current consumption on load resistance. The experimental conditions were as follows: we short-circuited the microphone and added an equivalent antenna. We measured the dependence of current consumption on the load resistance by varying the load resistance value. During this process, we recorded the total current consumption of the transmitter. The obtained research results are presented in Table 2.

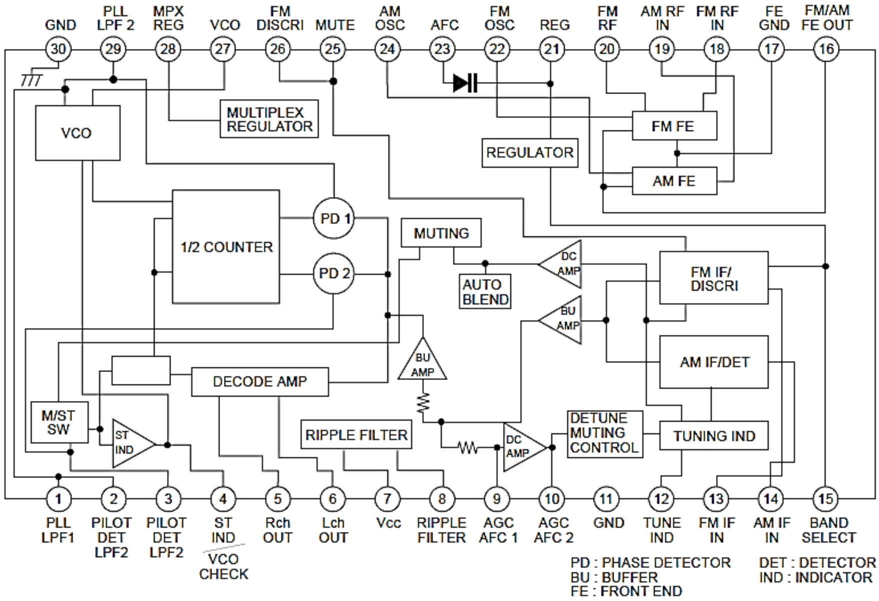


Fig. 10. Block diagram of the CXA1538S microchip [8]

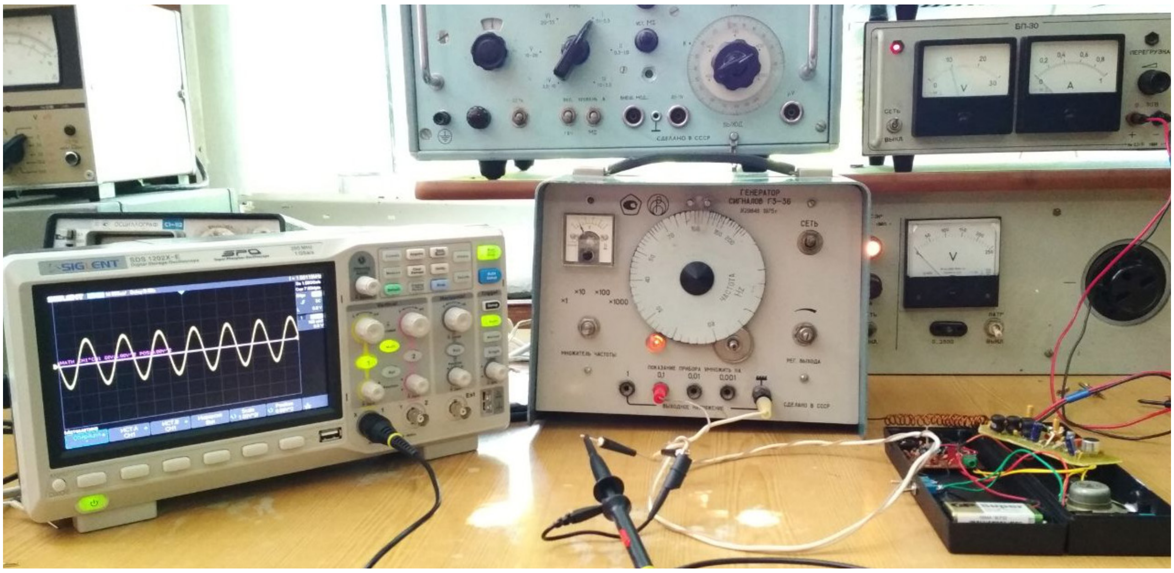


Fig. 11. Photo of the test bench for transmitter research

Table 2

Values of the current dependence on the load resistance

$I_{consumption}$, A	1,65	1,7	1,81	1,9	1,95
$R_н$, Ohm	1000	200	91	41,5	5,1

The graph depicting the dependence of transmitter current consumption on the load resistance is shown in Figure 14(b).

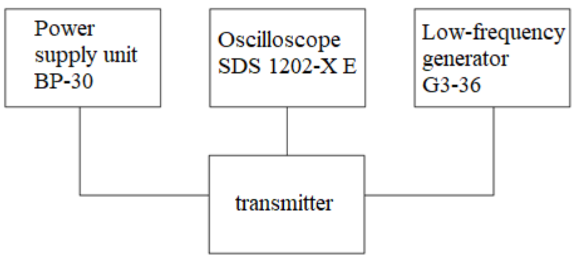
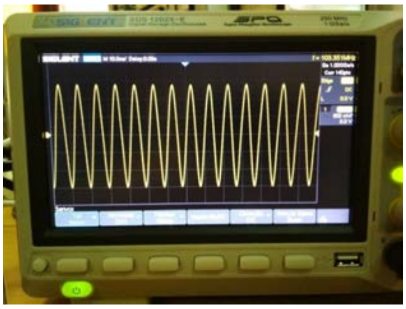
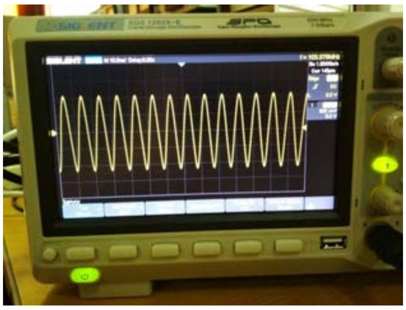


Fig. 12. Structural diagram of the test bench



(a)



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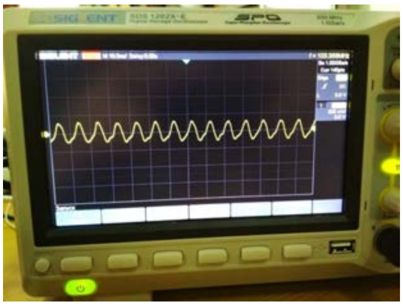
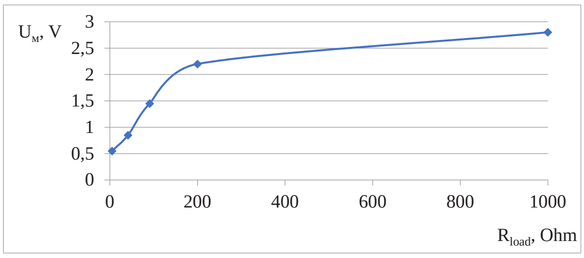
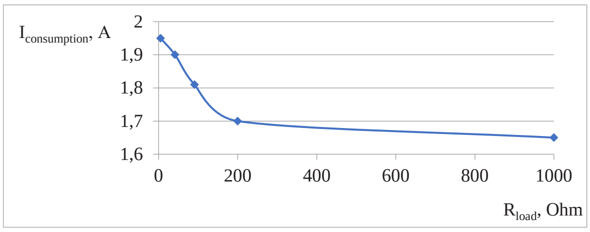


(c)

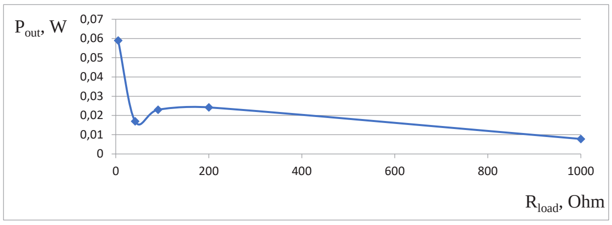
Fig. 13. Signal waveform at the transmitter output: (a) without load, (b) with Rload = 1 kOhm, (c) with R_{load} = 5.1 Ohm



(a)



(b)



(c)

Fig. 14. The results of the experimental study: (a) graph of the dependence of signal amplitude at the output on the load resistance; (b) graph of the dependence of current consumption on the load resistance (c); graph of the dependence of output power on load resistance

Table 3

Values of the dependence of output power from load resistance

P_{out}, W	0,059	0,017	0,023	0,0242	0,0078
R_{load}, Ohm	5,1	41,5	91	200	1000

Using the data from Table 3.1, we will determine the dependence of output power using Formula

$$P_{out} = \frac{Um^2}{Rload}.$$

The obtained results are recorded in Table 3.

Figure 14(c) shows the graph of output power's dependence on load resistance.

Conclusions. The authors proposed a new schematic solution for an amateur radio communication device in this work. They created a prototype of the device and conducted experimental investigations.

The experimental research on the operation of the radio communication device showed that the transmitter section operates at a frequency of 103.351 MHz. The amplitude of the transmitter's output signal is 1.5 V.

The analysis of the experimental research results indicates that the amplitude of the voltage increases with an increase in the load resistance while the power consumption of the transmitter decreases. The output power exhibits a decreasing trend with clearly defined local maximum and minimum.

Bibliography:

1. Mobile communications. Schiller, J. H. (2003). URL: http://197.156.112.159/bitstream/handle/123456789/1585/Mobile%20communications%20(%20PDFDrive%20).pdf?sequence=2 (Доступ 27 травня 2023 р.)
2. Шкідливий вплив електромагнітного випромінювання радіочастотного діапазону. URL: https://pubmed.ncbi.nlm.nih.gov/30870450/ (Доступ 27 травня 2023 р.) DOI: 10.1371/journal.pone.0213286

3. Agarwal, A., Singh, A., Hamada, A., & Kesari, K. Cell phones and male infertility: a review of recent technological innovations and consequences. International Brazilian Journal of Urology. 2018. 44(4), 662-681. doi: 10.1590/S1677-5538.IBJU.2017.0685

4. Пристрій-аналог радіозв'язку на транзисторах. URL: https://www.qrz.ru/schemes/contribute/constr/shema-prostoj-radiostancii-ukw-fm-diapazona-na-tranzistorah-i-kxa058.html (Доступ 27 травня 2023 р.)

5. Sklar, B. (2001). Digital Communications: Fundamentals and Applications (2nd ed.). Prentice Hall. ISBN: 978-0130847881

6. Як правильно налаштувати рацію. URL: https://pro-spec.ru/poleznaya-informaciya/124-kak-pravilno-nastroit-ratsiyu.html (Доступ 27 травня 2023 р.)

7. Підсилювачі низької частоти (ПНЧ). URL: http://moyaosvita.com.ua/fizuka/pidsilyuvachi-nizko%D1%97-chastoti-pnch/ (Доступ 27 травня 2023 р.)

8. Технічна специфікація мікросхеми CXA1538S. URL: https://www.alldatasheet.com/view_datasheet.jsp?Searchword=CXA1538S (Доступ 27 травня 2023 р.)

9. Радіоприймач MANBO S-202. URL: http://www.radioland.mrezha.ru/dopolnenia/manbo/manbo.htm (Доступ 27 травня 2023 р.)

Семенов А.О., Стальченко О.В., Притула М.О., Донський О.В. АМАТОРСЬКИЙ ПРИСТРІЙ МАЛОЇ ПОТУЖНОСТІ РАДІОЧАСТОТНОГО ЗВ'ЯЗКУ ДЛЯ FM ДІАПАЗОНУ

Стаття присвячена розробці пристрою радіочастотного зв'язку у вигляді аматорської радіостанції. Пристрій радіочастотного зв'язку є базовими елементом бездротових систем. Він отримав широке поширення у бездротових системах зв'язку широкого вжитку та спеціального призначення. Носимі пристрої радіочастотного зв'язку використовують в метровому та дециметровому діапазоні радіохвиль. Такі пристрої мають просту електричну схему та просту конструкцію. Тому розроблення нових електричних схем і створення нових конструкцій пристроїв радіочастотного зв'язку привертає значну увагу дослідників. Відома велика кількість публікацій. У цих публікаціях всебічно досліджені параметри та характеристики пристроїв радіочастотного зв'язку для систем спеціального призначення. Менше уваги було приділено розробленню та дослідженню аматорських пристроїв радіочастотного зв'язку. У роботі проведено аналіз різних умов роботи радіостанцій та їх вплив на потужність та частотний діапазон радіосигналу. Досліджено аналог пристрою радіозв'язку, та розглянуто його електричну принципову схему. У роботі запропоновано нову електричну схему передавача для пристрою радіочастотного зв'язку, створено дослідний макет пристрою та експериментально досліджені його параметри і характеристики. В статті представлені структурна схема пристрою радіочастотного зв'язку, електричні схеми блоку передавача радіочастотного зв'язку, підсилювача низької частоти, модулюючого генератора та каскаду підсилювача потужності. Передавальна частина пристрою працює на частоті 103,351 МГц, амплітуда вихідного сигналу передавача становить 1,5 В. Генерований пристроєм радіосигнал має частотну модуляцію та володіє малою потужністю. У результаті експериментальних досліджень побудовано графічні залежності амплітуди вихідного сигналу, струму споживання та потужності передавача від опору навантаження.

Ключові слова: *радіостанція, переговорні пристрої, радіочастотна передача, дальність зв'язку, автономність роботи.*