# Transmission of Control Signals Using Multiplex Analysis

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***ABSTRACT:*** *Inductive links establish two-way communication between the transmitter and receivers to transmit contactless energy. In wireless power and data transfer systems, the transmission of information and control signals contribute to the progress of technical and operational parameters. We have worked on the frequency multiplex analysis, and the results are presented in this work. Using a lab-based system, the output results are evaluated with systems and live experiments where the outcome is encouraging.*

**Keywords:** Contactless Transmission, Frequency Multiplexing, Two-way Communication, Wireless Power Transfer, Control Signals

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## 1. Introduction

In recent years, a number of companies and research teams have been working on transmitter-to-receiver communication in systems for contactless energy transmission [1, 2, 3, 10, 11, 12, 13, 15]. The bi-directional transfer of information and control signals through the power module was shaped as the current direction. There are different methods and schematic solutions to realize the parallel transfer of energy and data [2, 4, 5, 6, 7, 9]. To reduce the mass parameters and to improve the technical parameters, systems with a common inductive connection are used. One way to transmit power up to several kW and data up to 500 kBit / s is the frequency multiplier induction method [7, 9, 12]. The power transmission frequency is in the range of dozens of kilohertz, and the data transfer rate is in the order of megahertz to minimize the impact of one frequency to the other. This problem is very topical and in this report are presented analytical and computer studies at different frequencies and capacities of the two modules - power and information.

## 2. Frequency Multiplexing Scheme

The equivalent scheme for transmitting data from the transmitter to the receiver, based on the developed frequency multiplexing method [7,9], is presented in Figure 1. The transmitter module is composed of a high frequency generator with voltage $U_d$ and frequency $\omega_d$. With a unit in the transmitted data the voltage is supplied to the transformer $L_3$. It, together with the $C_R$ capacitor, forms a resonant circle set to frequency $\omega_d$:

$$\frac{1}{\sqrt{L_3 . C_R}} = \frac{1}{\sqrt{L_4 . C_S}} = 2\pi f_d = \omega_d \quad (1)$$

Similarly, in the receiving side, the receiving module is comprised of the inductance $L_4$ and the capacitor $C_S$, which form a resonant circle, set to the carrier frequency $\omega_d$, used to transmit the data. In this way, the data acquisition channel acts as a narrow line filter, which minimizes the impact of the power transmission channel.

Transformer $T_3$ performs multiplexing of the information signals and the frequency of energy transmitted to the load. $C_{L1}$ and $C_{L2}$ are parasitic capacities of the transmit and receive coils.

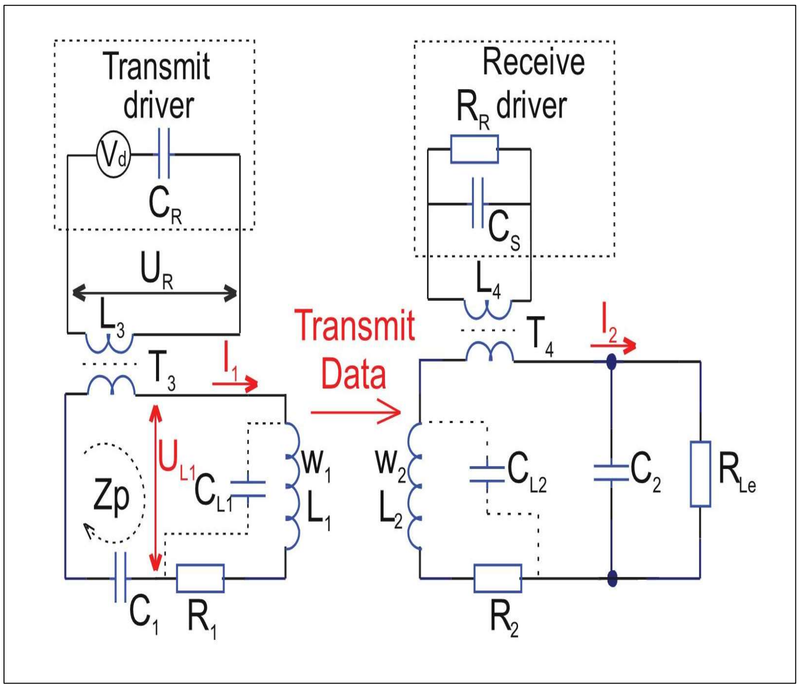



Figure 1. An equivalent scheme, used to transfer data from the power transmitter to the receiver

Multiplexing is performed by adding the frequency used to transmit data $\omega_d$: to the energy transfer frequency. When in the data has a logical unit, on the frequency for the transfer of energy is superimposed the frequency used for data transmission $\omega_d$. This algorithm is presented in the graphics shown of Figure 2.

In Figure 3. the equivalent data transfer scheme is presented in the opposite direction - from the receiving side to the transmitting side of energy. Analogous to the data transmission from the transmitter to the receiver, here the resonant circuits is composed of $L_3$ - $C_R$ and $L_4$ - $C_S$ and are set to the frequency $\omega_d$ used for transfer of data.

The scheme used for computer simulation is shown in Figure 4. The results for data transmission are presented in the following two figures. Figure 5 shows data transmission in the direction from the power transmitter to the receiver. In order to simulate data transmission in the direction from the receiver to the transmitter it was exchanged the circuits connected to $L_3$ and $L_4$.

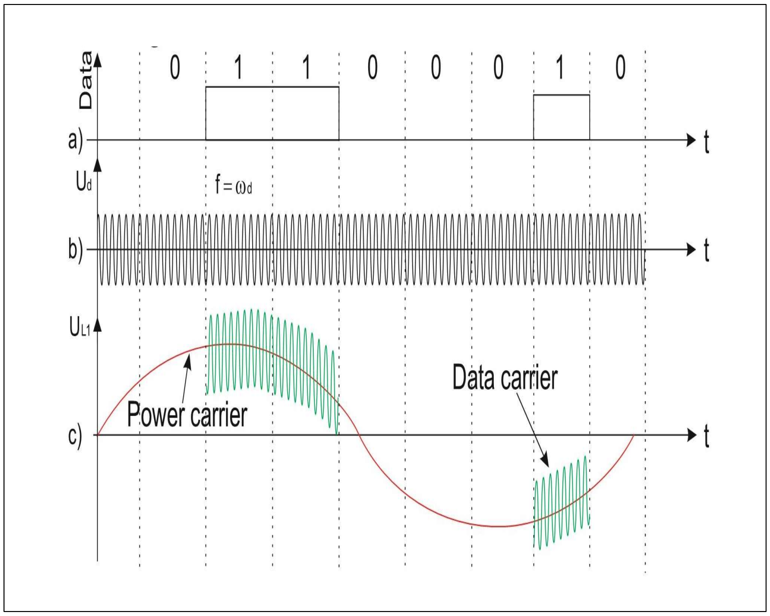



Figure 2. a) The chart of the transmitted information signal; b) The used data carrier frequency $\omega_d$;
c) The received signal from the overlaid frequency for transmitting energy and the frequency of data transmission

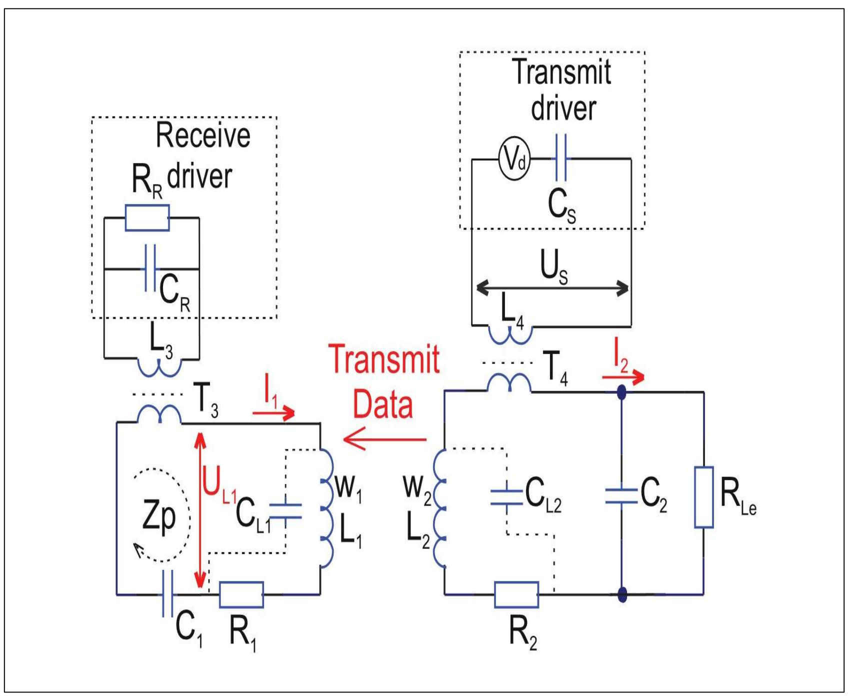



Figure 3. An equivalent scheme used to transfer data from the power transmitter to the receiver

In the Figure 6 shows the transmitting data from the receiver to the transmitter.

From the simulation and the results obtained in Figure 5 and Figure 6, it can be concluded that the developed frequency multiplexing method is applicable for power transmission [14,15] and bidirectional transfer of information signals at a power and control voltage ratio in both channels up to 20 times.

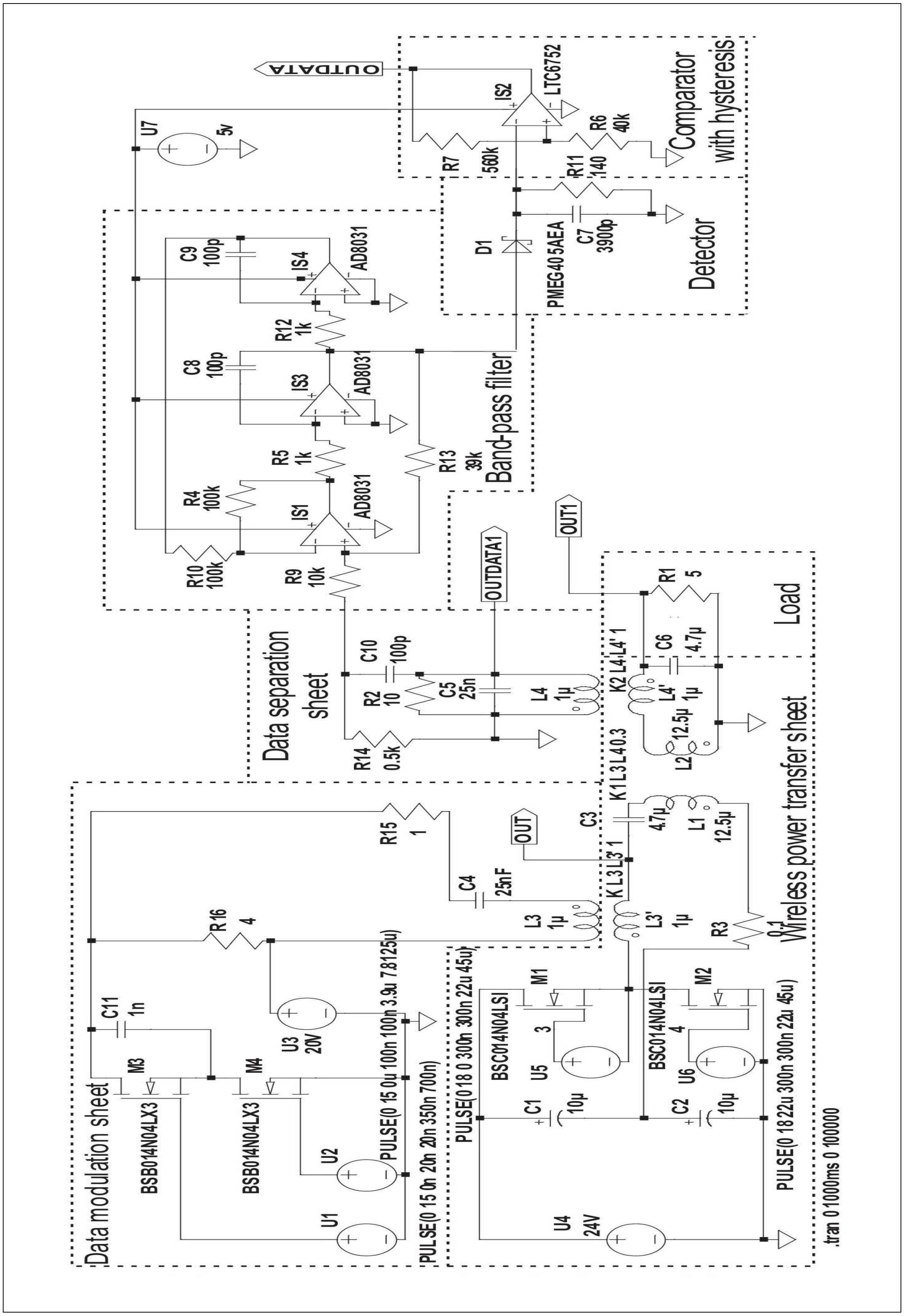



Figure 4. Schem5 used for computer simulation with program LTSPICE XVII

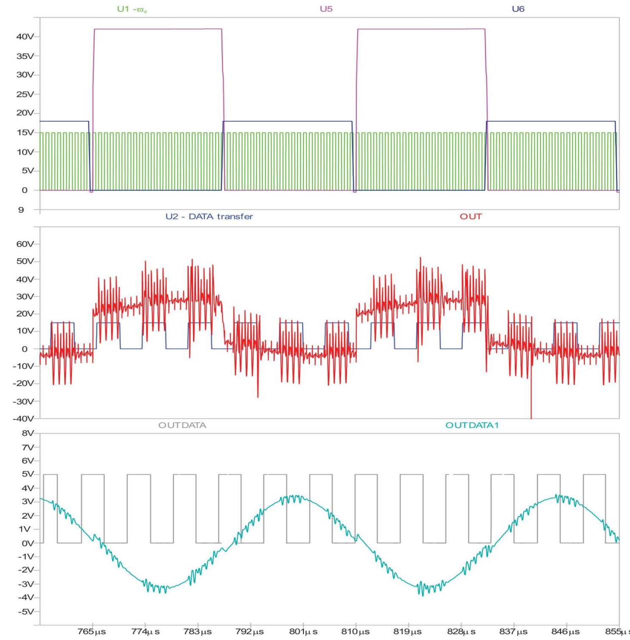



Figure 5. Computer simulation results at data transfer from the transmitter to the power receiver: U1 – data transmission voltage with frequency of $\omega_d$; U5 and U6 - the transistor M1, M2 gate voltage control; U2 - the voltage of the transmitted data; OUT - the voltage at the resonant inverter circuit; OUTDATA1 - the voltage at the receiving data coil; OUTDATA - the voltage of the data formed in the receiving part.

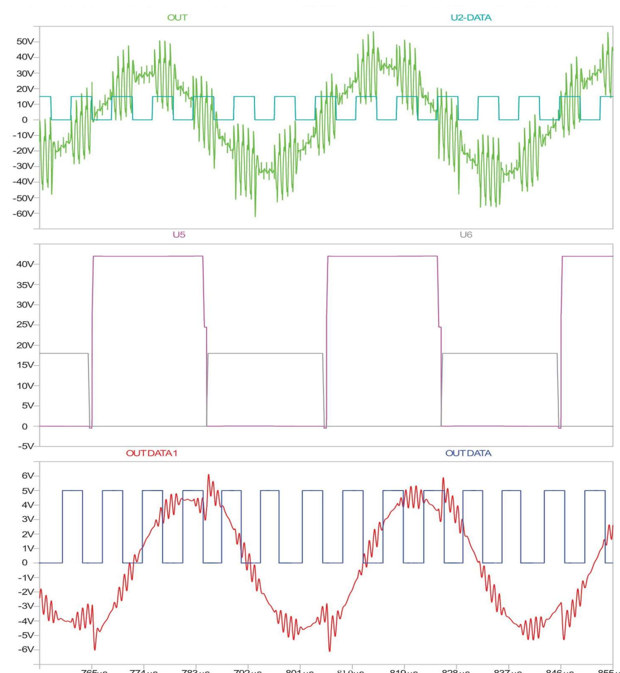



Figure 6. Computer simulation results at data transfer from the receiver to the transmitter: U2-DATA-voltage of transmitted energy from the receiver, OUT – voltage of transmitting data winding; U5 and U6 - transistor M1, M2 gate voltage control; OUTDATA1 - strip filter; OUTDATA - voltage of received data.

## 3. Practical Experiments

In order to verify the developed algorithm for parallel transmission of electrical energy and information signals by frequency multiplexing, a laboratory mockup has been developed. It is a scheme for powering and controlling the direction and speed of rotation of a DC motor. It visualizing the commands sent to the receiver and returned results and contains two principal schemes. The first one is an energy transmitter and a transmitter and data receiver Figure 7. In this circuit the PIC16F1713 processor controls the power transfer inverter and consists of U4, C5, C6, C7, C16, C18, D1, M1, M2, C17, L1, and T1. It also transfers the data to the energy receiver and receives the data from it, the scheme being implemented with Q1, Q2, Q3, Q6, Q7, Q8, VT2, VD1, VZ1, D2, U2, U3, R3, R4, R6, R7, R8, R9, R10, R12, R13, R14, R15, R19, R20, R24, R25, C8, C9, C11, C12 8 C15. The 1MHz high frequency used to transmit the data is generated by the processor. To visualize sent and received data a graphical LCD display 2x16 - DD1 is used. To select the transmitted ones, the UP and DOWN keys are used, and the ENTER button is used to send the selected command. ICs IS1 and IS2 provided the necessary additional supply voltages.

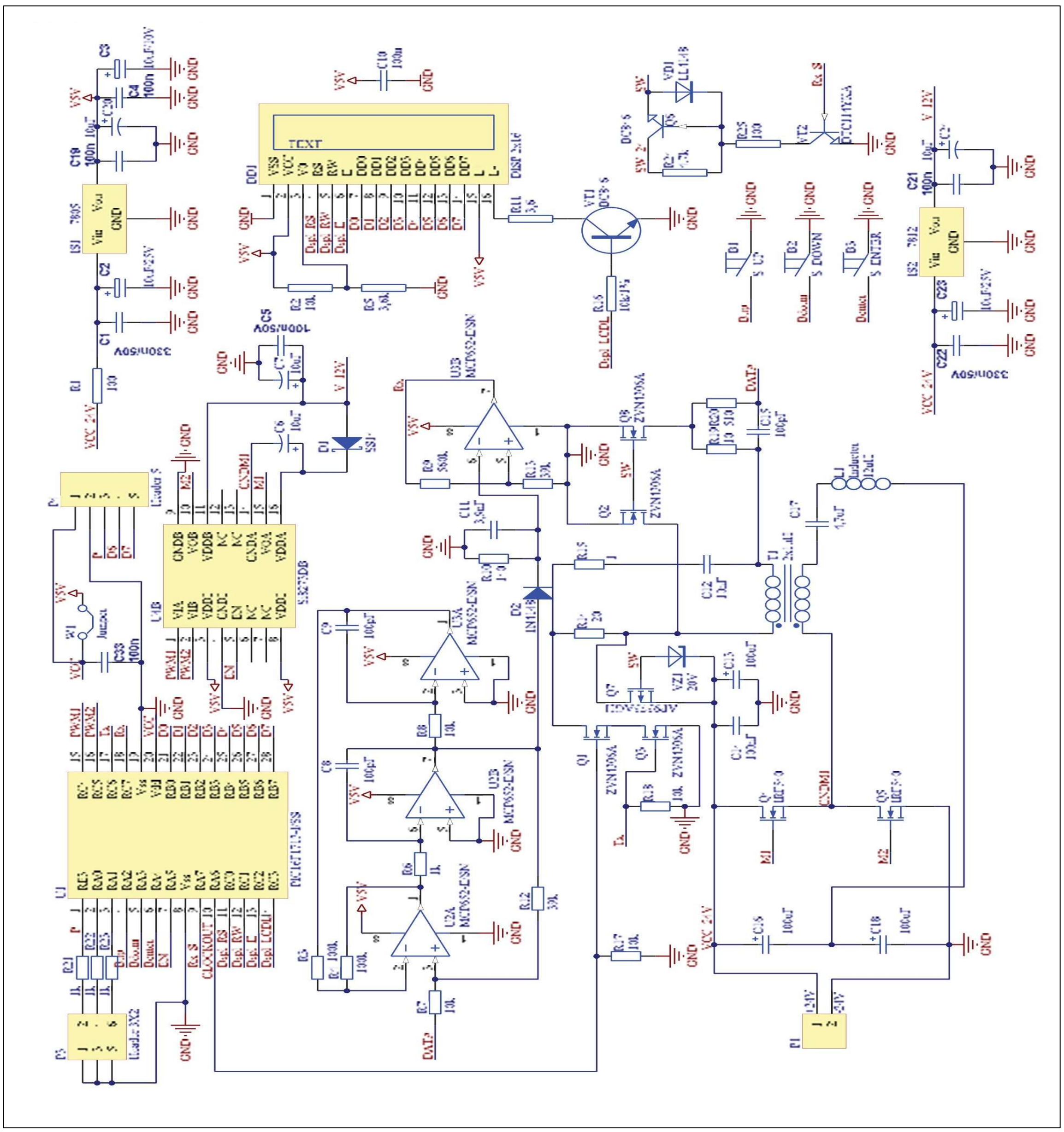


Figure 7. Scheme of the wireless power transfer and the data transmitter and receiver

The scheme of the wireless power receiver and the data receiver and transmitter is shown in Figure 8. In this scheme the PIC16F1713 processor is used for communication, direction control and speed, as well as voltage and current measurement of the DC motor. The communication scheme [8] is implemented with U2, U3, Q1, Q2, Q3, Q4, Q16, Q17, VT8, D1, VD2, VZ1, T1, R5, R6, R8, R9, R10, R11, R13, R14, R15, R17, R18, R19, R20, R52, R53, R59, R64, C12, C13, C14, C15, C16. The voltage is measured with the divider R65, R66, C34, which is connected to the rectifier D2, D8, D9, D10, and the current is measured with R61, R62, R63 and C18. Selecting the direction of rotation is controlled by VT6, VT7, Q5, Q13, Q14, Q15, R54, R55, R56, R57, R58, R60. By pulse width modulation delivered to Q14 or Q15, the motor speed is controlled. To visualize the received commands and the measured parameters, a graphical LCD display 2x16 - DD1 is used. The buttons are used to select the desired visualization parameter. IS1 provide power to the processor.

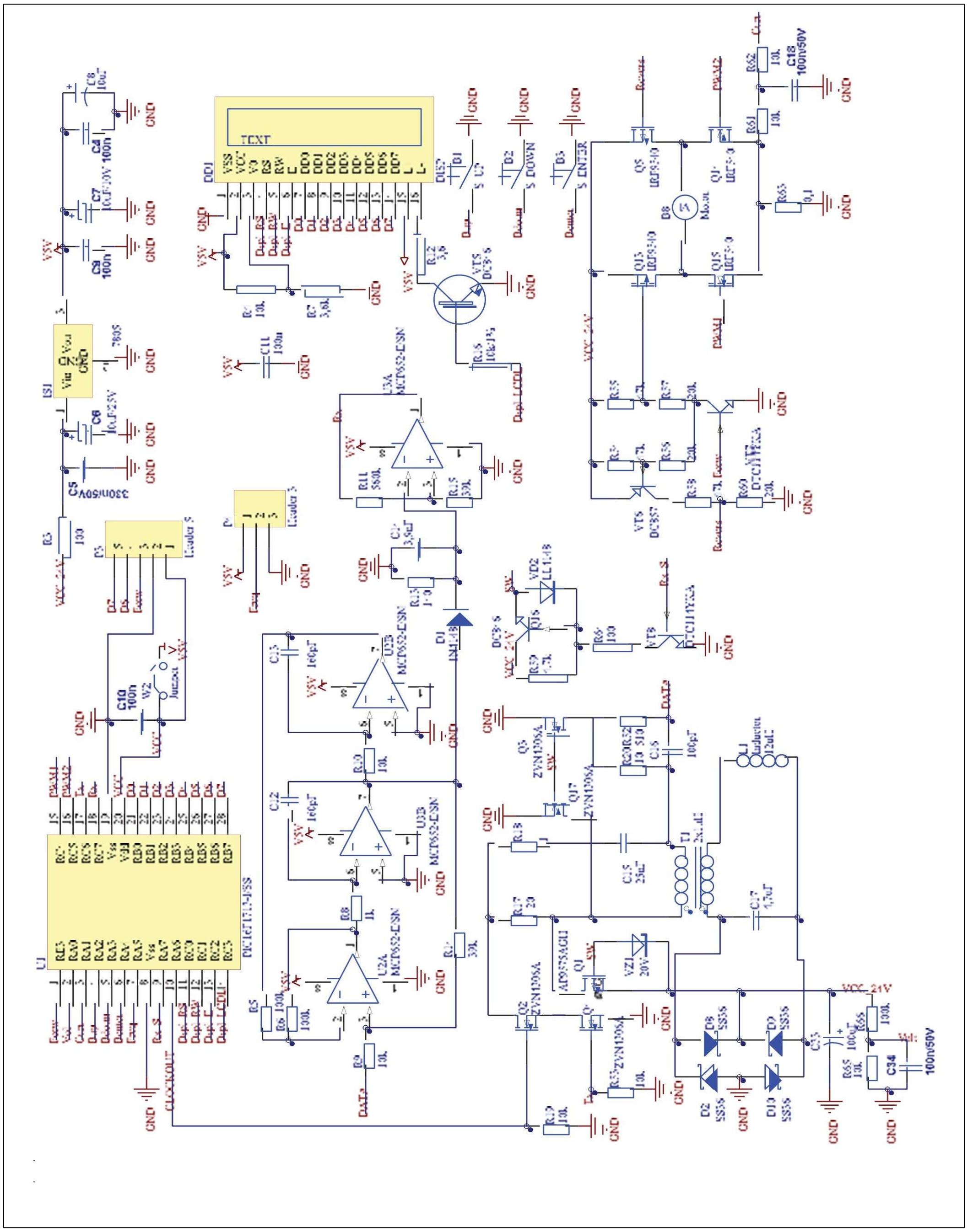


Figure 8. Scheme of the energy receiver, and the data transmitter and receiver

The experiments were performed in data transfer from the power transmitter to the receiver at a supply voltage of 24V and a distance of 2 cm between the windings of wireless module. The carrier frequency used to transmit the data is 998,780 kHz and the energy transfer rate is 20,810 kHz. The 4-channel adjustable stabilizer Twintex TP-4305 is used for power supply. To download the results, a 4-channel digital oscilloscope Tektronix TDS2014C was used. The developed model is presented in Figure 9.

The results are presented in Figure 10. a), b), c). The Figure 10. a) presents the high frequency $\omega_d$ voltage - CH1, the gate control voltage of the MOS transistors of the inverter - M1 - CH2 and M2 - CH3. On Figure 10. b) is shown the voltage of the transmitted data - CH1 and the voltage at the point between the transformer T1 and the condenser C17 - CH2. In Figure 10 c) represents the voltage at the input of the strip filter in the energy absorption scheme - CH3 and the voltage of the output of the comparator coming to the processor - CH1.

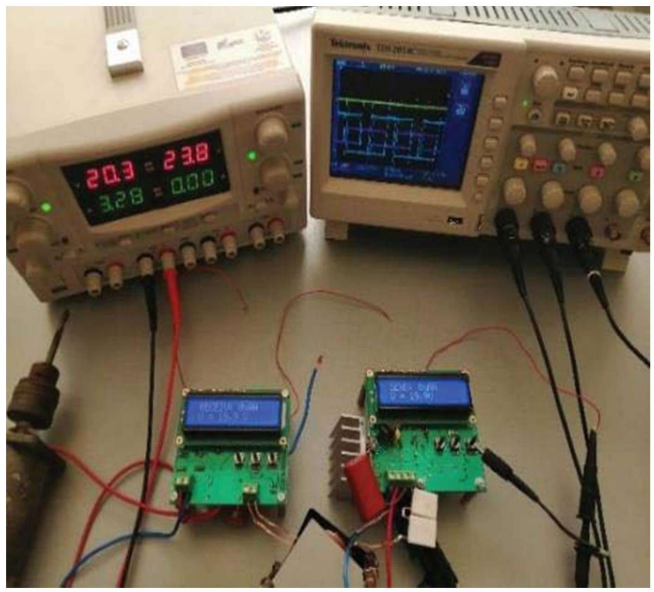
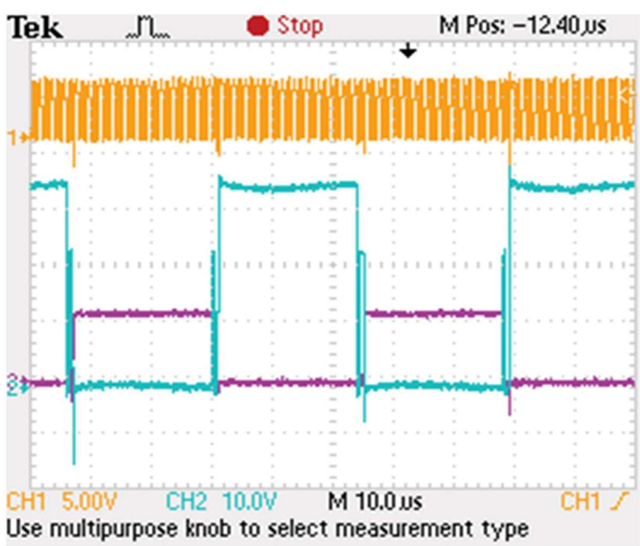
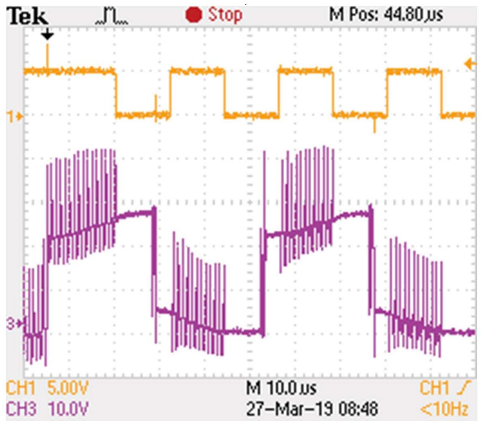



Figure 9. Wireless mockup




a)

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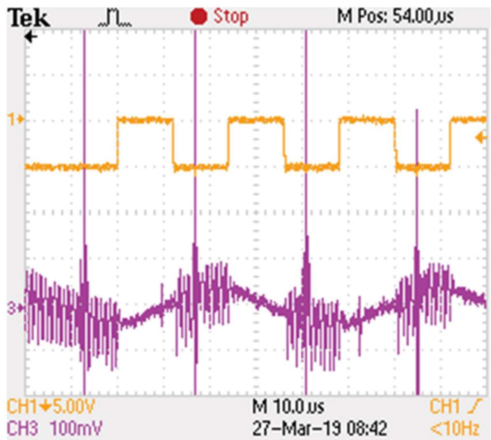


c)

Figure 10. Experimental results

## 4. Conclusion

From the applied scientific work, it can be concluded that the frequency multiplexing method can be used as a reliable tool for non-contact parallel transmission of energy and control signals. The computer and practical experiments with the developed laboratory model showed that we have a coincidence of more than 90%. The insignificant error between the results obtained from the two tests is due to differences in the components parameters used in the simulation and the limitations in the formed data parameters of the processor used. The method can be used successfully at power up to several KW and power and control voltage ratio up to 20 times. The method can be used successfully at power up to several KW and power and control voltage ratio up to 20 times.

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