EXPERIMENTAL RESULTS ON THE RADIO REMOTE CONTROL AND REMOTE MONITORING OF THE ANTI-HAIL MISSILE LAUNCHPADS

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Summary. The paper presents a technical solution for monitoring and operating the anti-hail missile launchpadsu sing an internet-connected wireless remote control, which operates in the 433 MHz ISM frequency band. A small size experimental model of the real launchpad wasdevised and built, in order to test the local operation of the remote control and its over-the-internet monitoring function. When designing the experimental model, attention was given to preserving the characteristics of the actual launchpad,such that after testing the technical solutions of the remote control on the model, they could be implemented on the real launchpad with minimal modifications.This experimental modelcan also be used for staff training during the active off-season. The proposed technical solution presents an example of how the electrical machine, seen as an element of execution, is included in the concept of the Internet of Things.

1. **INTRODUCTION**

The anti-hail system in Romania was createdunder the Government decision HG no.604 of July 28, 1999, regardingthe approval of the Program for the implementation and financing of the National anti-hail System andhasbeen systematically developed.The implementation of this systemis done through theGovernment'sannual decisions. First, theorganizational structureof the PrahovaTerritorial Unit was checked,andthe basic componentsofboth the anti-hail missileand the missile launchpad weremade. Then, throughinternal research such as Ph.D. theses andcontractresearch, these basic components weredeveloped and modernized. Any additional complementaryequipmentuseful for activeinterventions in theatmospherewas added.

The experimental model of the anti-hail missile launchpads was designed to verifythe technicalsolutionsfor the remote control, operatedlocally or from the Command Centerlocated at 50-80km [1].

2. **THE REMOTE CONTROL**

2.1 Making the remote control

The radio remote control is built with two ASD-DTU-100 transceivers that use LoRa modulation. They provide the radio link between a touch screen used by the operator and a PLC controller connected to the launchpad, using a frequency in the 433 MHz ISM band (fig. 1) [7], [8].

The commands entered by the operator are grouped in into three pages on the touch screen: manual positioning, automatic positioning, and the list of events. Positioning the launchpad from the automatic positioning screen, and launching the missiles are considered as events. All the events are recorded on an external SD card or a USB flash,which is attached to

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the remote control. In parallel with the touch screen, the launchpadpositioning and the missile launching commands can be sent from a local control panel, connected by cables to the PLC controller. The remote control has an Ethernet port, which makes the remote monitoring and control of the launchpad possible when using a computer connected to the Internet. Access to the remote control is password protected and can be disabled by the local operator.

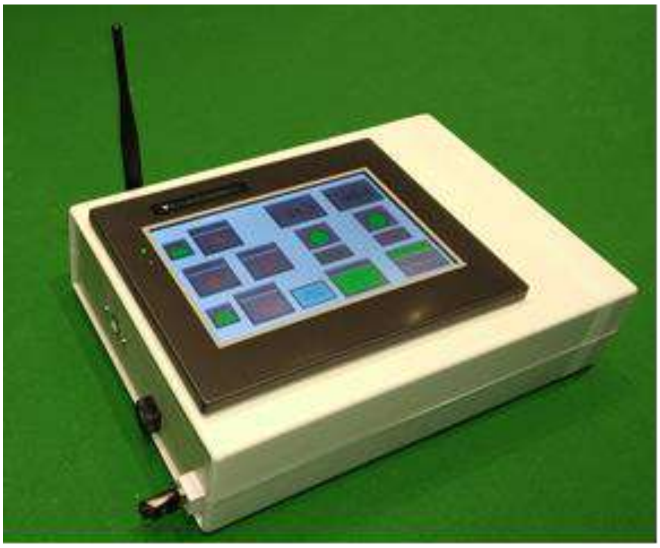

Fig. 1. The remote control

2.2RF measurements

A field test was performed in an urban environment, to measure the operating range of the radio remote control. Power was provided from the internal battery, andthe transmitter's power was setto11 dBm (12.59 mW). The remote controlfunctioned correctly for up to90 m, after whichtheradio signalwas lostduetoattenuationand a loss of the direct line of sight. The radio link was resumed at 60m.

The frequency spectrum and the transmitteroutput power measurements were performed on a test bench using an Agilent N9010A signal analyzer. The remote control was connected to the signal analyzer through a ZFRSC-42-S+ Rf splitter [10] andtwo radiofrequency cables provided with SMA connectors.

The transmitter maximum output power and frequency spectrum measurements were performed usingthe Trace – Max Hold function ofthe Agilent N9010A tester (fig. 2).

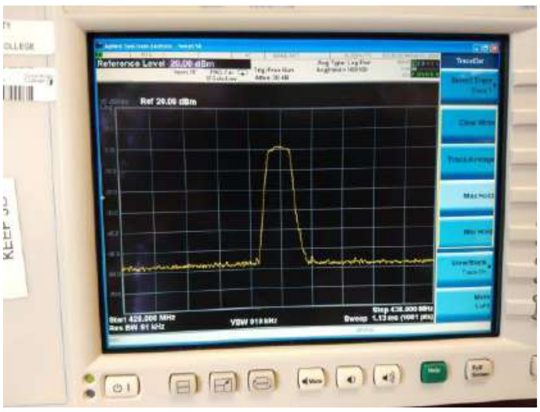

Fig. 2. The transmitter maximum power and frequency spectrum measurements usingTrace – Max Hold function of the tester.

A maximum of 2 dBmtransmitter output power was measured, which confirmsthe maximum power of 11 dBm set for the transmitter, considering the RF splitter attenuation of 6 dB and the power loss on cables andconnectors of about 3 db.

LoRa type modulationis well known for the very low average transmitted power, dueto the 1% or less on-air duty cycle, limited by regulations. Figure3 shows the result ofthefrequency spectrumandthe average transmitter output power measurements, usingthe Trace – Average function of the Agilent N9010A tester for the same transmitter settings as in maximum output power measurements presented in figure 2.

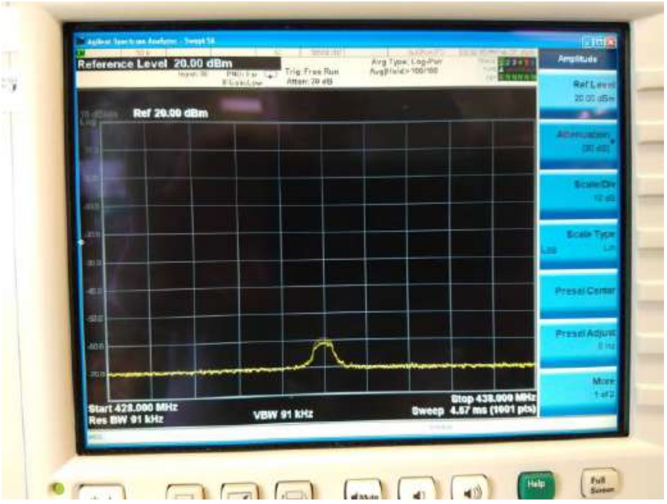

Fig. 3. The frequencyspectrum and the average transmitter output power measured with theAgilent N9010A testerusing the Trace –Average function.

It can be seen from figures 2 and 3 that the level of the radiated power outside the 1 MHz RF channel is 30 dB lower than the maximum power, whichmeans that 99.9% of the power is radiated inside the chosenfrequency channel. This proves the high spectral efficiency and adjacent channel power performance of the transmitter.

The very low measured averagetransmitter output power is not at allsurprising. LoRa-type modulation and LoRaWAN communication protocolhave been specifically created forlow-volume data communications betweenisolated,battery-powered sensorsandinternet-connectednetwork nodes,where energy saving is a priority.

3.**THE EXPERIMENTAL MODEL OF THE LAUNCH RAMP**

3.1 The mechanical structure ofthe experimental model

The experimental model, shown in the figures (4.-6.), reproduces the positioning function of the actual launchpadon azimuth and elevation and simulates thelaunching of two missiles[2], [9].

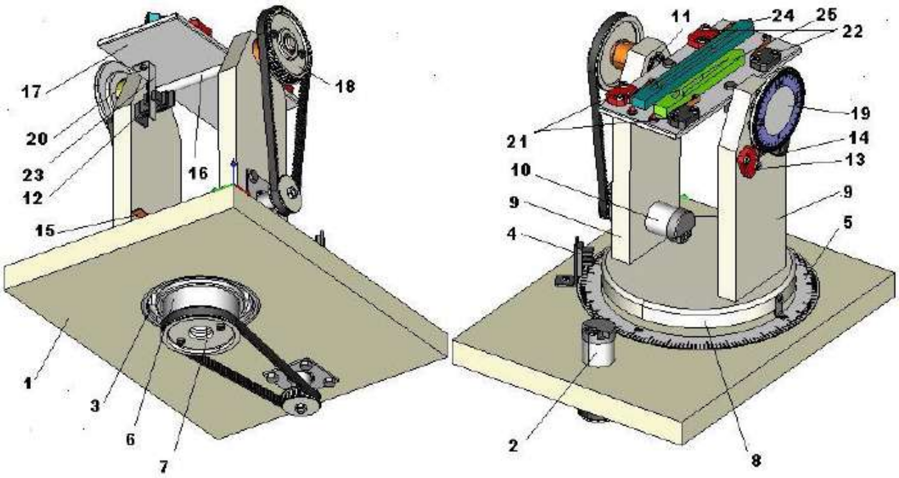

Fig. 4.The experimentalmodeldrawing

Thefigure 4 legendis illustrated in table1.

Tab.2. Figure 4 legend

Reference number	Explanation
1	Base plate, 338 x 257 x25 mm, Delrin
2	DC motor, azimuth (SPG30E-270K)
3	Bearing, azimuth (110 x 70 x 20 mm)
4	Home position sensor, azimuth (Omron EE-SX460-P12)
5	Circular scale, azimuth
6	Cylindrical shaft, Delrin, L=55 mm, D=70 mm, azimuth
7	Timing pulley, 40 teeth, 57105K28, azimuth
8	Rotating plate, azimuth, D=180 mm, H=18 mm, Delrin
9	Vertical walls, Delrin
10	DC motor, elevation (SPG30E-270K)
11	Bearings, elevation (30 x 10 x 8 mm)
12	Home position sensor, elevation (Omron EE-SX460-P12)
13	Limit switch, elevation 20°
14	Limit switch, elevation 85°
15	Cable clamp
16	Shaft, L=160 mm, D=10 mm, elevation
17	Missiles plate, 204 x 80 x 6 mm, Plexiglas acrylic
18	Timing pulley, 40 teeth, 57105K28, elevation
19	Circular scale, elevation
20	Cam, elevation, for 20° and 85° limit switches
21	Microswitch, detects missile presence
22	Microswitch, detects missile type
23	Home position sensor mobile element, elevation
24	Long missile
25	Short missile

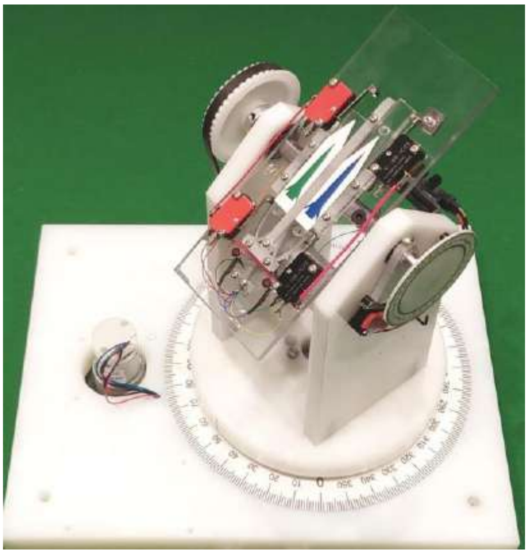

Fig.5.The experimental model ofthelaunchpad

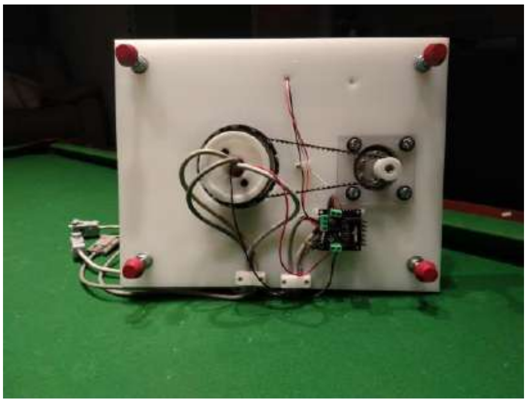

Fig.6. The experimental model -bottom view

3.2 Choosing the electrical components of the experimental model

Two SPG30E-270K DCgeared motors were used for the positioning of the experimental model (fig. 7).

Fig. 7. SPG30E-270K DC motor used forazimuth and elevation positioning

The transmission ratio of the motor gears is 1:270. An external 1:4 gears and timing belt transmission is present in both the azimuth and elevation directions.

The DC motors have 1.1 W of power, at 12V nominal voltage[3].

The quadrature encoders on the motors require 5V DC power and provide7 pulses per revolution.

Considering:

N1 = 270 the transmission ratio of the motor gears,

N2 = 4 the transmission ratio of the gears and belt,

N3 = 7 pulses per revolution at the motor shaft

Thenumber N of pulses provided by the encoders for one-degreerotation of the launchpad on either of the two axes – azimuthor elevation - can be calculated (1):

$$\boldsymbol{N} = \frac{\boldsymbol{N_1 N_2 N_3}}{\boldsymbol{360}} = \boldsymbol{21} \quad (1)$$

The pulses on both the A and B encoder channels are countedby the PLCwhile the launchpad is moving,and the number Ndetermines the maximum accuracy ofthe positioning, which is theoretically 1/84 degrees (fig.8). The positioning accuracy is lowerdue tothe mechanical play inthe bearingsand the elasticityof the transmissionbelts.

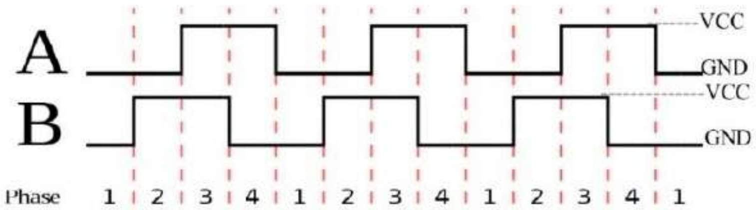

Fig. 8. The quadrature encoder output pulses

Althoughthe DC motors have a nominal voltage of 12V, they were powered with 5V, to reduce the rpm. The decreased power does not affect thenormal operationof the experimental model. Thus,themodel executes a full rotationin about 55 seconds.

The driver module used to control the two DC motors is presented in fig.9 [4].

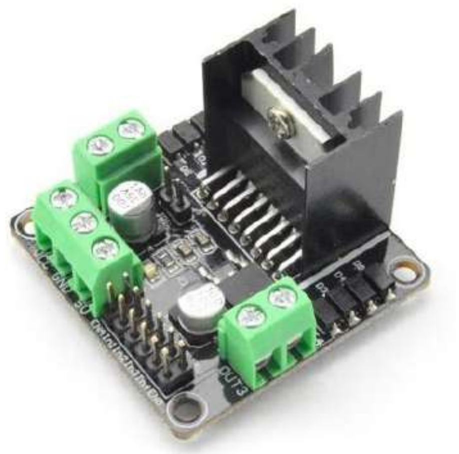

Fig. 9. The driver module used to control thetwoDC motors

The driver module, based on the L298N integrated circuit, can drive a step-by-step motor or two DC motors, as inthisapplication.

The driver module's electronic schematic is shownin fig. 10 [5].

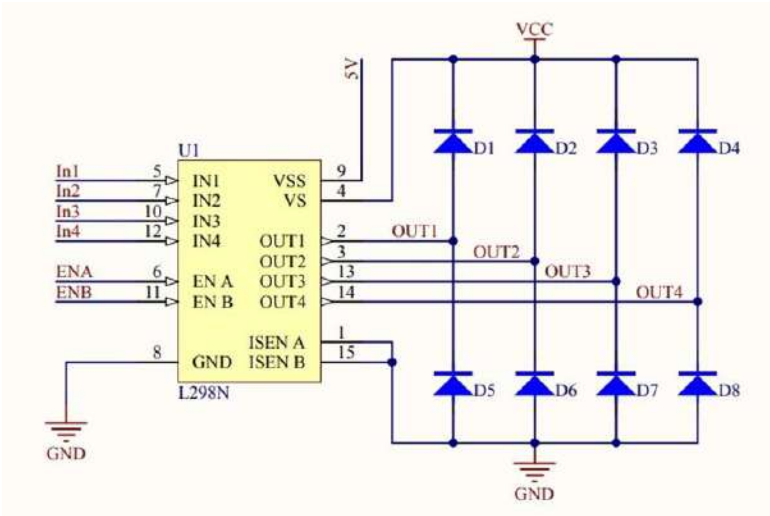

Fig. 10. Electronic schematicof the driver module

The integrated circuit L298N contains a dual bridgewith transistors and can drive inductive loads, such as step-by-step motors or DC motors, at a voltage of up to 46V and a total maximum current of 4 A [6].

The choice of the DC motors and the driver module when designing the experimental model was not randomly taken. The twoDC motors connecttotheOUT1-OUT2and OUT3-OUT4 driver outputs. The control inputs for the driver module are IN1, IN2,andENA for the azimuth motor, and IN3, IN4, and ENB for the elevation motor. The control of the twoDC motors is similarto thatof the AC motors on theactual launchpad,where each motor is driven by anintelligent AC drive, with the FWD, REV, and ENABLE control inputs. Only the voltage levels are different: the driver module on the experimental modelworkswith 5V signals, and the AC drives control inputs accept24V signals.

Thelogic used by thedriver module is illustrated intables 2and 3.

Tab.2. The logic commandsfor theazimuth motor

IN1	IN2	Ena	Azimuth motor
X	X	0	Stop
0	0	X	Stop
1	0	1	Rotate to the right
0	1	1	Rotate to the left

Tab.3.The logic commands for the elevation motor

IN3	IN4	ENB	Elevation motor
X	X	0	Stop

0	0	X	Stop
1	0	1	Increase elevation
0	1	1	Decrease elevation

The electrical diagram oftheexperimental model is presented in fig.11.

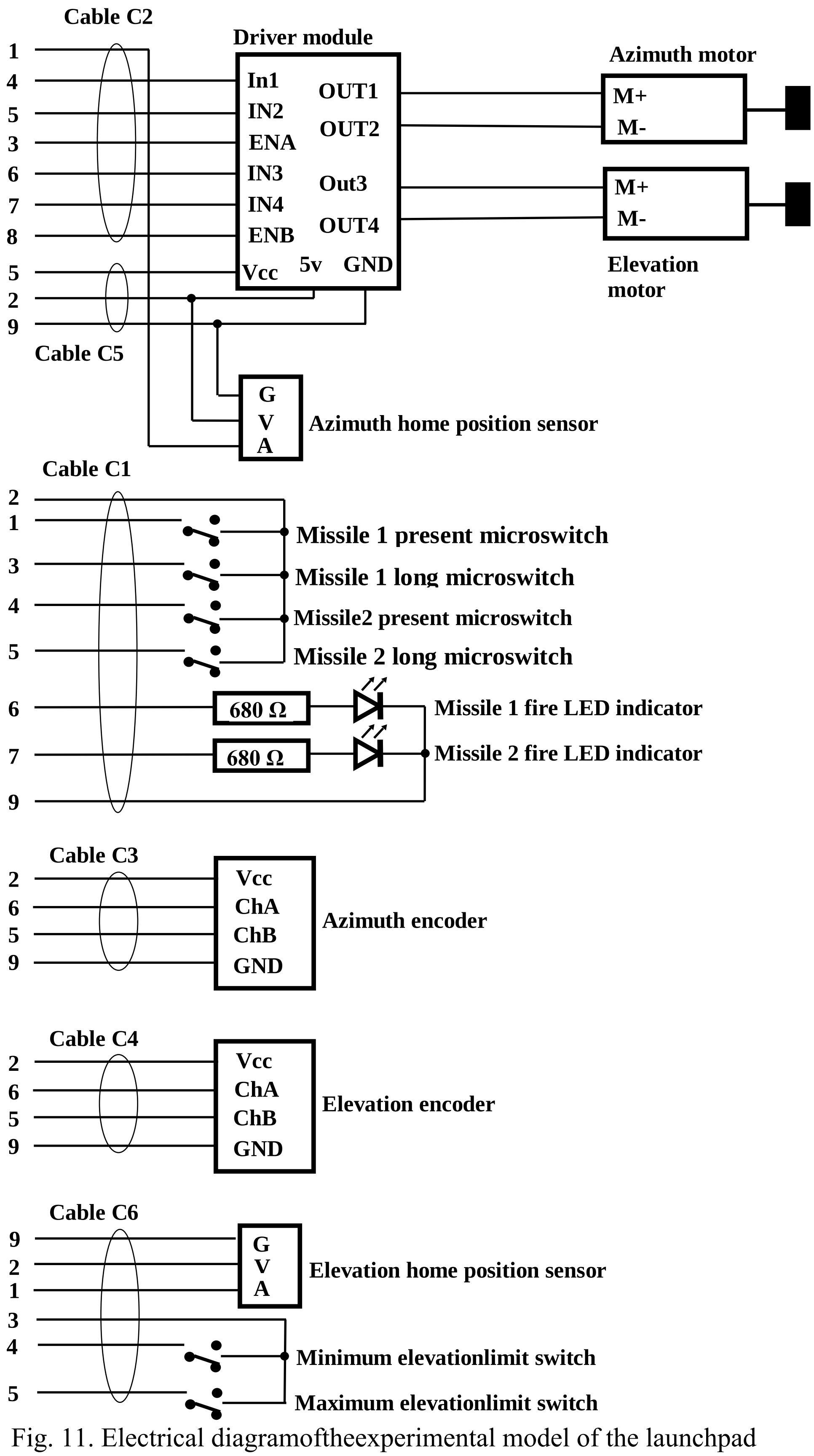

Fig. 11. Electrical diagramoftheexperimental model of the launchpad

4. **MONITORING THE MISSILES LAUNCHPADIN THE COMMAND CENTRE**

To remotely connect to the touch screen using an internet-connected computer, a supervisor in the Command Centre only needs:the IP address of the router to which the touch screen is connected, the account nameandthe password. An internet browser must be used, and no additional software is required. Another option is to use an iPhone or iPad tablet, in which case the C-more Remote HMI free app must be installed.

To monitor the launchpad in the Command Centre, the following settings must be performed on the remote control and the router:

- Set the samestatic LAN IP address for thetouchscreen and PLC. The Default Gatewaysetting is the router's LAN IP address, usually 192.168.0.1 or 192.168.1.1, depending onthe routertype.
- Set the DNS server address to the address being taken from the router configuration.
- Enable the Web Server application on the C-more program loaded on thetouchscreen.
- Select port 80 for the Web Server app.
- Enable the Remote Accessapplicationonthe C-more programloaded onthetouch screen.
- Selectport 11102 for the Remote Access app (fig. 12).
- Open ports 80 and 11102 from the Port Forwarding menu of the router to which the touchscreen is connected (fig.13).
- Specify the router WAN IP Address inthe Remote Connection tabon the Remote Access app.
- Setthe user accounts View, View & Screen Change,and Full Control in the RemoteAccess app, with or without setting a password.

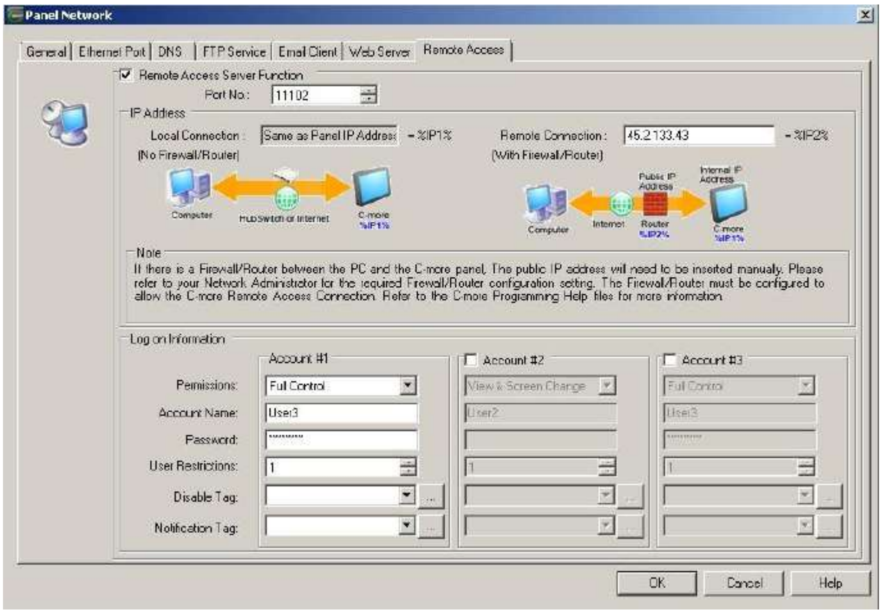

Fig. 12.Remote Access app settings

Fig. 13.Port Forwarding router menu settings

5. CONCLUSIONS

The experimental model of theanti-hail missile launchpad presentedin this paper was designed and built for the purposeoftestingthe prototype of a remote control for the launchpad.

During the designing and building process of the launchpad experimental model and the remote control, the authors took the mechanical and electrical characteristics of the actual launchpad into account. The remote control can be easily implemented in the production of the actual launchpad with minimal modifications, and the experimental model can be used to train the operator personnel in the Anti-hail System.

The paper presented here is an example of how the electrical machine, seen as an element of execution, is included in the concept of the Internet of Things.

Acknowledgment

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Authors 'contributions

First author – 90%

Second author – 10%

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