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AUTOMATED VERIFICATION COMPLEX FOR MOBILE COMMUNICATION SYSTEMS

Ua Надані основні результати, отриманні при розробці, виготовленні та експериментальному дослідженні автоматизованого повірочного комплексу для систем мобільного зв’язку. Розроблений комплекс дозволяє здійснювати оцінку відповідності та періодичну повірку СВТТР і СШПООІ, які використовуються операторами мобільного зв’язку, що дає змогу забезпечити правильність розрахунків між споживачем та постачальником телекомунікаційних послуг.

Ru Предоставлены основные результаты, полученные при разработке, изготовлении и экспериментальном исследовании автоматизированного поверочного комплекса для систем мобильной связи. Разработанный комплекс позволяет осуществлять оценку соответствия и периодическую поверку СИДТР и ССПУОИ, используемых операторами мобильной связи, что позволяет

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обеспечить правильность расчетов между потребителем и поставщиком телекоммуникационных услуг.

Formulation of the problem

One of the priority and most important directions of the socio-economic development of the country is the innovative development of the communication industry and the introduction of leading modern technologies in the creation and improvement of telecommunication facilities.Stable development of the information and telecommunication infrastructure is the basis for strengthening the competitiveness of the economy and integration of Ukraine into the global information society. It is an opportunity to improve conditions and quality of life of a person through access to national and world information resources.In modern telecommunication market, telecommunication operators are focusing on expanding the list of services and improving their quality.

In most countries, according to a study conducted by «A.T. Kearney», the requirements for quality assurance of telecommunication services relate to universal services, fixed telephone services, mobile services and Internet access [1].

Mobile services and access to Internet resources have grown rapidly through the wide range of capabilities. They provide: communication and search for diverse information, quick product purchases and instant billing, navigation and object search on the terrain etc.

When providing services to telecommunication operators, the volume of services is calculated in order to charge them (by the duration of the communication, by the amount of received and/or transmitted information; without limiting the amount of data with the restriction on the speed of transmission) and by determining the subscriber payment system.

Systems for measuring the duration of telephone conversations (SMDTC) and the system of transmission speed and accounting of the information volume (SSTAVI), in accordance with the resolutions of the Cabinet of Ministers of Ukraine "On approval of the Technical regulation of legislatively regulated measuring instruments" and "On approval of the list of categories of legislatively regulated measuring instruments are subject to periodic verification", belong to the legally regulated measuring equipment and are subject to conformity assessment and periodic verification. On this basis, the development of verification complexes for SMDTC and SSTAVI becomes relevant [2, 3].

Verification complexes for SMDTCand SSTAVI in organizations and enterprises of Ukraine that perform metrological activities in the field of telecommunications, as a rule, operate in manual or semi-automatic modes, which complicates the verification procedure and, thus, increases the likelihood of errors made by the expert. Automated complexes of domestic and foreign production have excess functionality and high enough cost [4-7]. The above is another indication of the urgency of developing an automated verification complex for mobile communicationsystems (AVC) that would meet the criterion "required functional-price-quality". Therefore, development is very important in terms of import substitution.

The purpose of this article is to highlight the main results obtained from the development of an automated verification complex for mobile communication systems.

The main content

The implementation of the automated verification complex for mobile communication systems is carried out in order to carry out the conformity assessment and periodic verification of the SMDTCand SSTAVI in the automatic mode, aimed at guaranteeing the correctness of the payments between the consumer and the telecommunication service provider, as well as to save money and time and to reduce the probability of errors when conducting these works.

The peculiarity of the AVC is to measure two parameters simultaneously – the amount of information (the amount of data transferred) and the duration of the communication session. In doing so, magnitudes of different nature are investigated: amount of information (bits) and duration (seconds).

The AVC includes a microprocessor subsystem for real-time clock module synchronization, since the error of the SMDTC test is the error of the time interval standard and accurate timing of calls. AVC consists of hardware and software parts.

The hardware of the automated verification complex for mobile communication systems

The block diagram of the AVC is shown in Fig. 1.

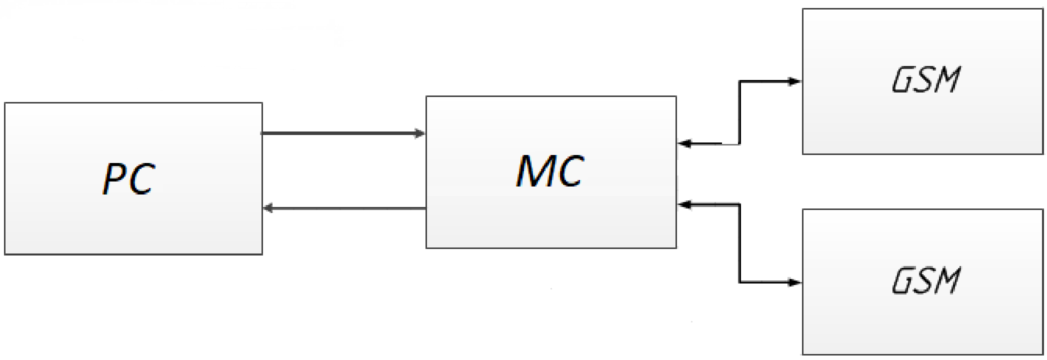


Figure 1. Block diagram of the AVC forSMDTC and SSTAVI
(GSM – GSM module; MC – microcontroller;
PC – personal computer)

The AVC is designed according to the modular principle of Arduino Mega board construction [8]; SIMCom Wireless Solutions GSM/GPRS module SIM800 Series [9] and GSM/GPRS Shield SIM900 Series [10], which are analogues of mobile phones/modems and personal computer (PC) [11, 12].

The Arduino Mega board is built on the ATmega 2560. The main advantages of the board are the reproducibility, cheapness and availability, as well as the cross-platform of the microcontroller.

GSM / GPRS Shield based on SIM900 component is used within the complex for the verification of the SSTAVI. Shield SIM900 has a TCP/IP stack implemented and contains MediaTek's MT6260SA chip and RFMD RF7176 chip. Unlike its counterparts, the Shield SIM900 supports a wider range of AT commands and has better performance for optimal file download performance and for connecting an SD card directly to the GSM/GPRS module. In turn, the SIM800L GSM/GPRS module, unlike other modules in this series, is more reliable because it has higher energy efficiency, is easy to operate and also has an affordable price. This module is the best solution for measuring the duration of telephone calls, as it supports the modern standards of mobile communication and data transmission and a number of AT commands. To provide monitoring and control of the verification of the volume of information while using telecommunication services, it is possible to manage simultaneously the process of packet data transmission and to measure the duration of its transmission – this is an important difference of this verification complex and helps to investigate values of various kinds: duration (hours, minutes, seconds, milliseconds) and amount of information (bits).

Two GSM GPRS modules are used for communication between two subscribers in the AVC, developed on the basis of Arduino Mega 2560 module. However, such a microprocessor module does not provide the necessary accuracy of time intervals and does not provide the ability to store the time scale required for the verification of the systems for measuring the length of telephone conversations. The stability research of a quartz generator built into the Arduino Mega 2560 board was carried out in the laboratory of the State Enterprise «All-Ukrainian State Scientific and Production Centre for Standardization, Metrology, Certification and Protection of Consumer», (SE «Ukrmetrteststandard») using an Agilent 53132A frequency meter and the Memmert VO200cool thermocamera (Fig. 2). As a reference frequency, a 5 MHz signal was sent to the frequency meter from the State SecondaryStandard of the Units of Time and FrequencyVETU07-01-03-10 [13].

The results of the research showed that the quartz generator built into the Arduino Mega 2560 does not provide the required accuracy of time intervals and does not allow the timeline to be stored in the SMDTC verification complex (Fig. 3).

Figure 2. Stabilityresearch of a quartz generator built into the Arduino Mega 2560 board

Period, s	Temperature, °C	Period
10:00	20	1,0087458513
10:30	20	1,0087462415
11:00	20	1,0087467264
11:30	20	1,0087471516
12:00	20	1,0087478394
12:30	20	1,0087482494
13:00	20	1,0087487365
13:30	20	1,0087491515
14:00	20	1,0087496252
14:30	20	1,0087502541
15:00	20	1,0087508245
15:30	20	1,0087513454
16:00	20	1,0087532555

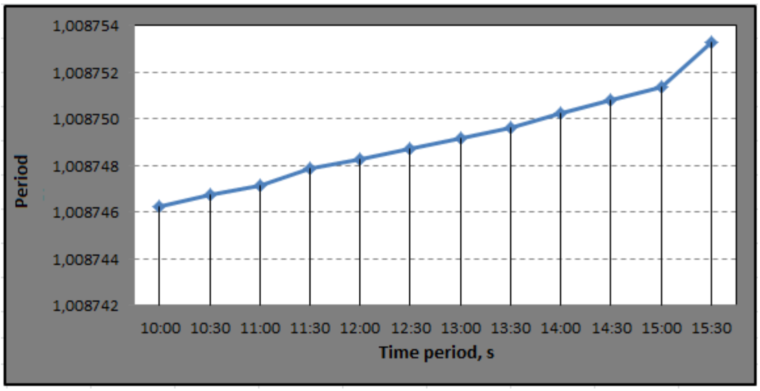


Figure 3. Error of a quartz generator built into the Arduino Mega 2560 board

Therefore, it was decided to create a microprocessor subsystem within the AVC synchronization module real-time clock based on the use of an external module of the real time clock – Real Time Clock (RTC).

In this regard, a detailed analysis of existing RTC modules with the possibility of connecting to the Arduino Mega 2560 was carried out and RTC DS1307 [14] and DS3231 [15] were selected for further research (Fig. 4).

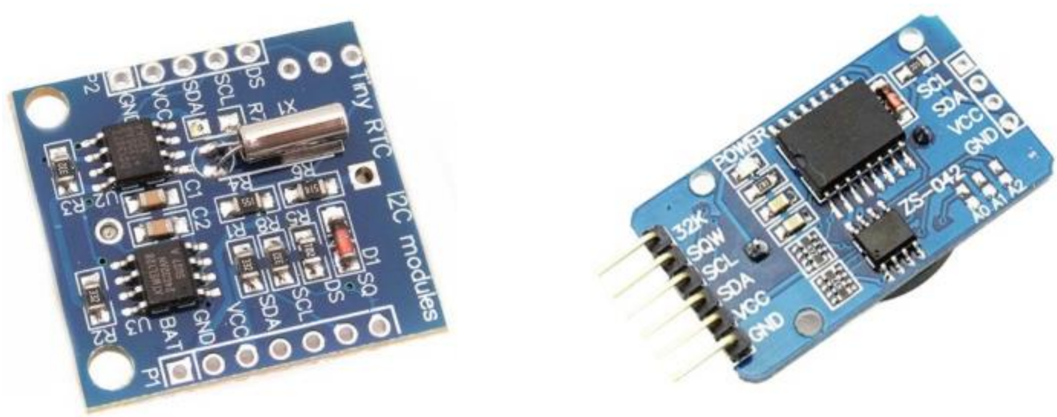


Figure 4. Modules of the real time clock DS1307 and DS3231

The results of the study of the daily running of RTC modules have shown that they are not stable, the frequency of modules over time is increasingly different from the nominal one. Because RTC are programmed to a specific nominal frequency, and it may vary, real-time modules will deviate from the reference time value. Accordingly, the more time has passed since the modules started to work, the higher error.

For simplicity of interpretation, suppose that the error increases by linear law (red line in Fig. 5). Therefore, you must constantly adjust the RTC to ensure that the error value does not exceed a certain value. In this case, the error of the real-time clock when synchronized is shown in Fig. 5 by the green line.

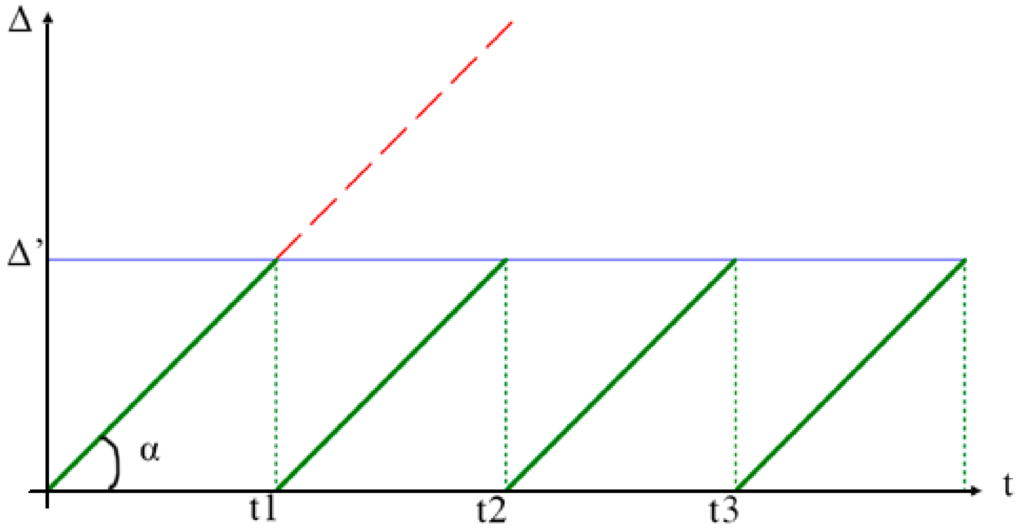


Figure 5. Error of module of RTC during synchronization

In Fig. 5, Δ –is the frequency error, Δ’–is the maximum value of the AVC frequency error, which allows the verification of SMDTC, assuming that the error of the standard must be at least three times less than the error of the measuring instrument, α– is the angle characterizing the velocity increase in value of error, t1, t2, t3 – are moments of synchronization, t – is time. Δ’in the complex under development will be known when the SMDTCerror is known, which is to be verification. In this case, Δ’, in the worst case, should be 3 times smaller than the error of SMDTC. The error is characterized by an oblique straight line, and the rate of increase of the error value is characterized by the angle α. Thus, knowing the angle α and Δ’, it is possible to find the coordinate of the point t1, which will indicate the time interval when synchronization is required. In the future, the time intervals will be the same.

Summarizing the above mentioned factors, the error in the verification complex for SMDTC will never exceed the set norm.

The formula for finding the time interval t1:

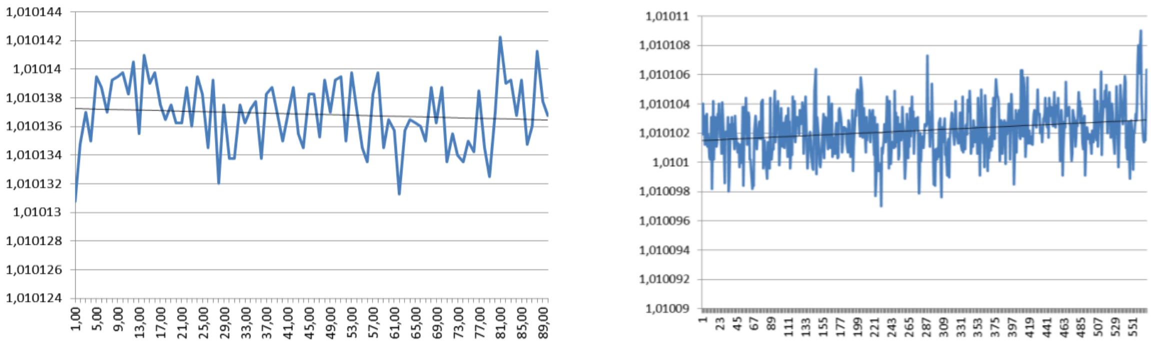
$$\Delta' = k \cdot t.$$

If the angle α = 45’, k= 1

$$T1 = \Delta' / k.$$

Synchronization of the RTC module should not be done frequently as it will consume CPU resources. During the synchronization, it will not be possible to perform the SMDTC verification. To synchronize time, be sure to pause verification, synchronize, and then resume verification. Therefore, it is important to choose the time module with the lowest rate of error growth.

Research of quartz generators in the selected modules showed that the daily rate of the quartz generator in RTC DS1307 at 23 °C is 0,000001 s per hour or 0.000024 s per day, and in RTC DS3231 – 0,0000004 s per day (Fig. 6). Therefore, the daily stroke and the temperature coefficient of the daily course of the DS3231 module quartz generator are 60 times less than the DS1307.



Module - temperature	DS3231	DS1307
20 °C	0,00000936 s	0,000013 s
23 °C	0,0000004 s	0,000024 s
	DS3231	DS1307
Daily dependence on temperature	2,99e-6 s/°C	3,67 e-6 s/°C

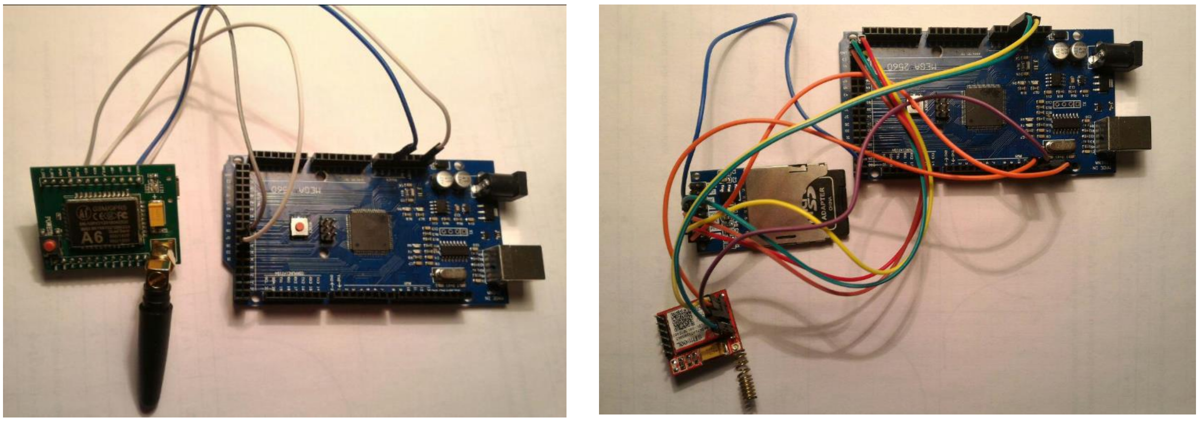
Figure 6. Research of the daily rate of the quartz generators in RTC DS1307 andDS3231

Thus, the RTC DS3231 module is included in the microprocessor subsystem of the clock synchronization module.

Fig. 7 depicts the hardware implementation of AVC for SMDTC and SSTAVI.

Software part of automated verification complex for mobile communication systems

In order to verify the system for measuring the length of telephone conversations, according to the verification method [16], the expert, using the user interface, enters the telephone number for making a call, the number of calls to be made and their duration. After that, the system operation mode is selected: A-B(A) – the mode in which the call is made from SIM800 module to SIM900 module, SIM900 receives the call and from that moment the time entered begins, after this time passes, the SIM800 module must disconnect and telephone conversation ends; A-B(B) – the mode in which the call is made from SIM800 to SIM900, SIM900 receives the call and from that moment the countdown of the entered time begins, after which the SIM900 module should disconnect and the telephone conversation ends. The microcontroller acts as a GSM modem and connects to the cellular network using AT commands to control the GSM module, thus transmitting data via the microcontroller communication channel. It is necessary to create a separate session for each telephone conversation, since the main task is to verify telephone conversations for a certain duration. The start and end time of the session is specified in minutes. Immediately after the end of the verification, the expert requests a session data from the mobile operator, which allows to calculate the time error. Because the verification complex is connected to a computer, it allows you to quickly retrieve large amounts of information, process it, and store it for future reference.



a) *b*)

Figure 7. Hardware implementation of AVC for: *a*) SMDTC; *б*) SSTAVI

A block diagram of the algorithm for the functioning of the AVC for SSTAVI and SMDTC is shown in Fig. 8.

A block diagram of the algorithm for real-time clock module synchronization as an integral component of AVC work for SMDTC, which provides accuracy sufficient for SMDTC verification, is shown in Fig. 9.

When starting the software, the expert has the opportunity to get acquainted with the menu, which consists of two tabs: SMDTC, SSTAVI (Fig. 10). The *SMDTC* tab is designed to enter the appropriate data to perform the SVTTR verification procedure and to initiate the verification procedure (*Execute* button). The *SSTAVI* tab is divided into two parts. The first is used to make sure you connect to the desired accounting system and to select a file with the connection settings (the file contains the access point of the mobile operator, APN, depending on the verification mode (reported by the mobile operator)). When connected, the operator requires a data request. If the accounting system is not the one you need, then the session is interrupted and a new connection is made (GSM module can be deactivated – often necessary for switching to another accounting system (a feature of mobile networks). If the accounting system is the one you need, it must be shut down without de-energizing the module.

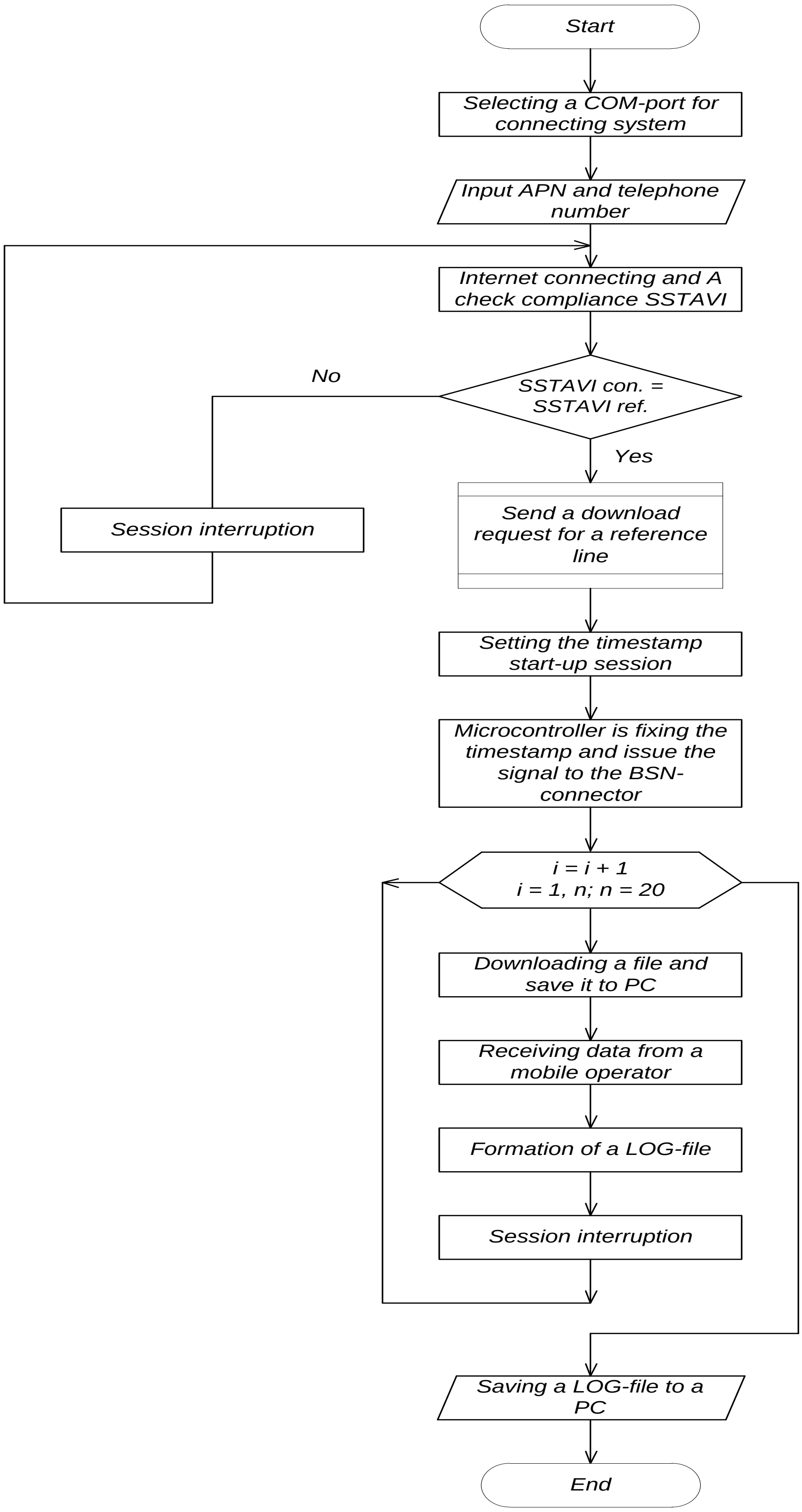


Figure 8. Block diagram of the algorithm for the functioning of the AVC

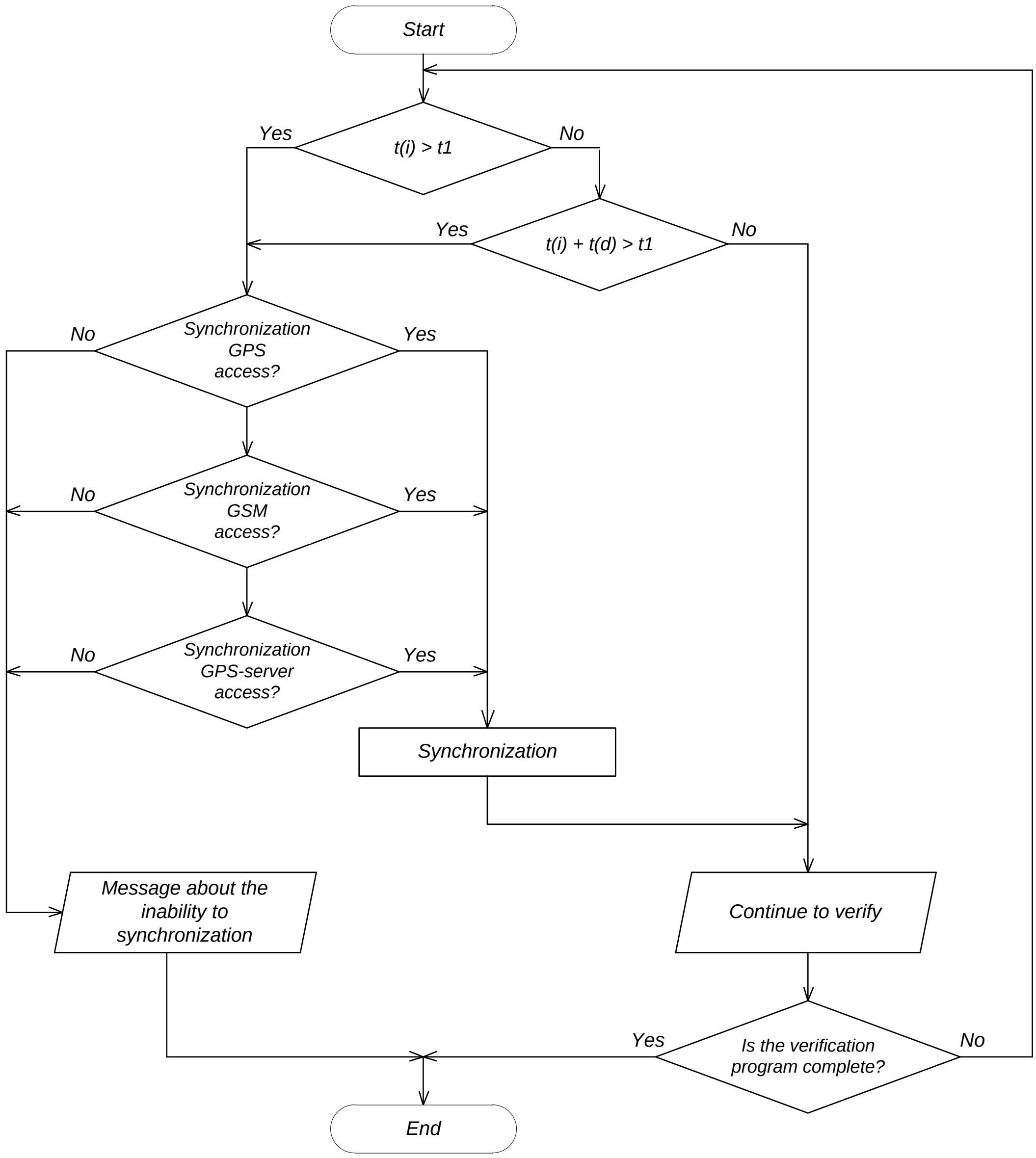
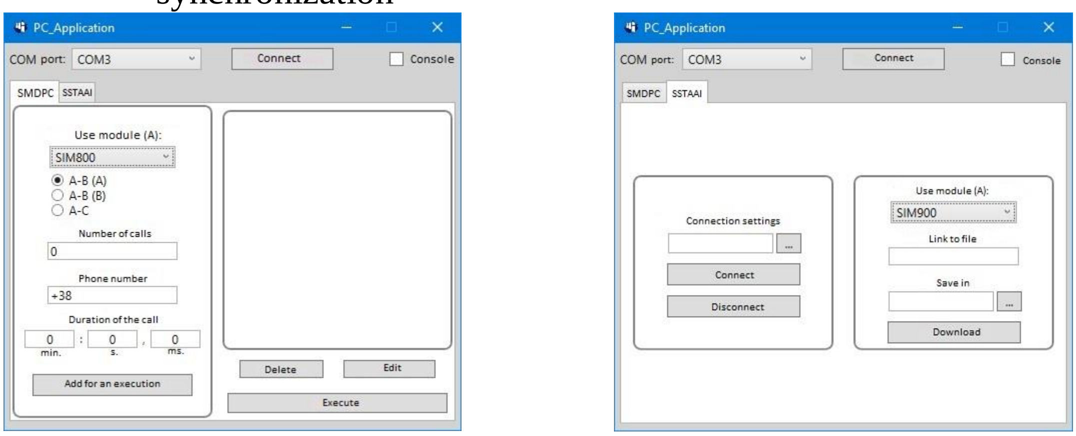


Figure 9. Block diagram of the algorithm for real-time clock module synchronization



a) *b*)

Figure 10. Tabs: *a*) SMDTC; *b*) SSTAVI

The log file stores data: date, time, SIM-card number, session time, number of bytes (UpLink / DownLink). The *Connect* button is used to establish an Internet connection based on the settings made (the possibility (button) to disconnect from the Internet is provided). The second part is intended for the verification procedure of the SSTAVI. It is possible to enter a link to a downloaded file and select a directory to save it by operating system or manually.

Also above the tabs there is an expandable list of available ports for connecting the Arduino card and a button for connecting to the selected port.

For full operation of the developed user interface for performing data acquisition operations for connection, checking of network connection, connection / disconnection to the Internet, transfer of the reference file to the PC, determination of the number of uplink / downlink bytes), data transmission for the log-file (session duration, number of bytes) a microcontroller was programmed on the Arduino board. The controller software has the function of issuing to the BNC connector a signal with the set parameters (in Complex Check mode). The microcontroller software is developed in the special Arduino 1.8.3 software environment.

The general appearance of the Android user interface for the AVC is shown in Fig. 11.

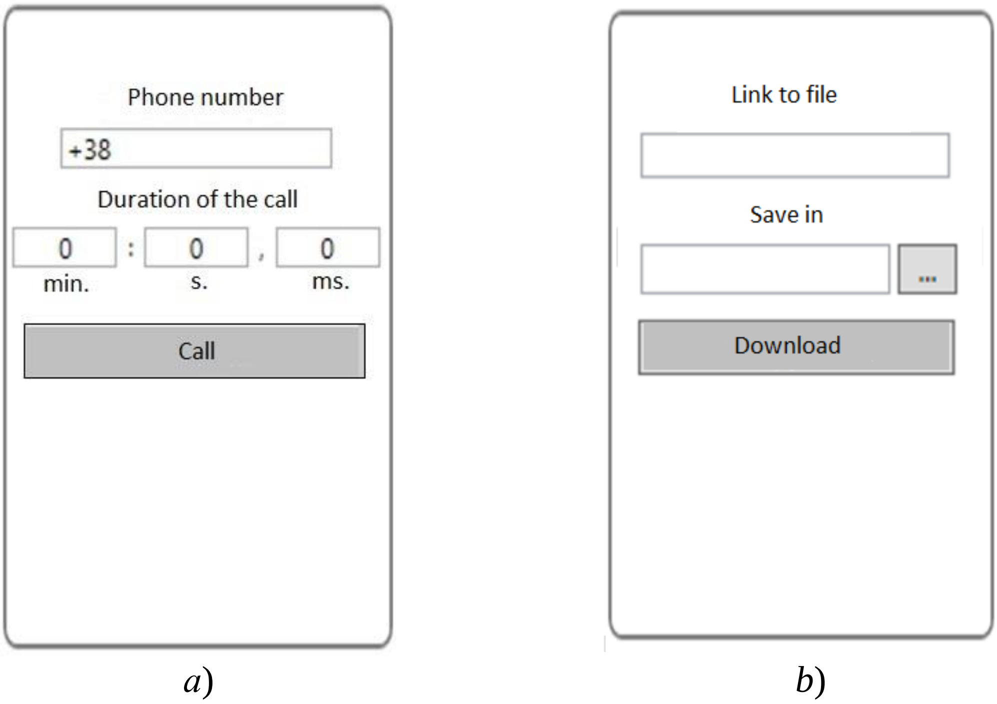


Figure 11. Software implementation of AVC for: a) SMDTC; б) SSTAVI

During the verification of the SMDTC and the SSTAVI, the values of the measured lengths of telephone conversations and the amount of information downloaded from the Internet are recorded in the experimental research protocol. At the same time, the mobile service provider introduces data on the duration of these sessions and their billing, after which the measured and obtained data are compared and a verification protocol is automatically generated.

Conclusions

The basic results obtained from the design, manufacture and experimental research of an automated verification complex for mobile communication systems are provided.

The developed complex allows to carry out the conformity assessment and periodic verification of the SMDTC and SSTAVI used by the mobile

operators, which allows to ensure the correctness of the calculations between the consumer and the telecommunication service provider.

The implementation of this complex is especially relevant for organizations and enterprises engaged in metrological activities in the field of telecommunication.

The use of the developed complex will allow: to reduce the probability of errors of the personnel, who perform the verification; reduce the cost of metrology by reducing staff time and increasing verification productivity.

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