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FEATURES OF AUTOMATED SPECTRUM MANAGEMENT SYSTEM AT 27th SUMMER UNIVERSIADE IN KAZAN

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Key words: *radiomonitoring, automated system, spectrum management, major event, application service, interference investigation, direction finding, locating radio sources, equipment testing, labelling, radio control equipment, software, service radio, Universiade*

July 6 to 17, 2013, Kazan hosted XXVII World Summer Universiade where 351 medals events in 27 sports were held to more than twelve thousand participants from 162 countries, which was a record for all student games. For the Universiade 64 sports facilities were involved, 33 of them were directly used for the competition. Twenty-four thousand law enforcement officers ensured law and order. More than 120,000 guests visited the Universiade, three Russian and thirteen international broadcasters provided live transmissions. More than 120,000 guests visited the Universiade, three Russian and thirteen international broadcasters provided live transmissions. More than thirty television commentators, two hundred cameras and fifteen mobile television stations worked on daily basis [1].

Such large-scale sporting event inevitably was accompanied by a sharp increase in the concentration of radio transmitters within a limited area. Additionally electronic devices with a very high variety of different types were used for radio and television broadcasts, operative communications of event organizers and sports delegations, security and medical services, a large number of wireless microphones and video cameras, numerous wireless data networks, etc. appeared.

Success of such event is impossible without efficient planning and allocation of radio frequencies, radio-electronic equipment testing and licensing and reliable monitoring of their use in real time. For operational processing of the use of electronic equipment that are received at the last moment, especially fast and flexible frequency management directly to at the site are required [2]. In such circumstances, it is advisable to use high-performance Automated Spectrum Management and Monitoring System (ASMMS). ASMMS should provide registration and licensing of radio electronic equipment, check their electromagnetic compatibility (EMC), detect and localize unauthorized radio electronic means (REM) and sources of interference and to manage the personnel.

The purpose of this article is to show the main technical aspects of Universiade 2013 ASMMS automated system during preparation and holding of XXVII World Summer Universiade in Kazan that was the largest in world history.

Technical features of Universiade 2013 ASMMS

Universiade 2013 ASMMS is a modification of domestic ARMADA Automation Spectrum Monitoring System (ASMS) [3] that was supplemented by essential features to monitor the spectrum at large public events.

The system is developed based on International Telecommunication Union (ITU) recommendations [4-5]. It has a multi-level hierarchical architecture, and the same software used at all levels. The system has client-server scalable and cross-platform architecture, it provides interfacing with other information systems. Special system features include a broad use of Web-based technologies and open standard radio equipment control protocol, this makes it possible to use radio monitoring equipment (RME) produced by various manufacturers.

The main components of the system include the radio monitoring equipment, server and client software, engineering and technical infrastructure.

Universiade 2013 ASMMS included the following items shown in Figure 1:

1 Unattended fixed monitoring stations (FMS)
2 Unattended fixed object monitoring points stations (OMS)
3 Mobile radio monitoring stations (MMS)
4 Portable radio monitoring equipment which is used by radio monitoring and interference search groups (RMSG)
5 Labeling and measurement laboratories (LML).

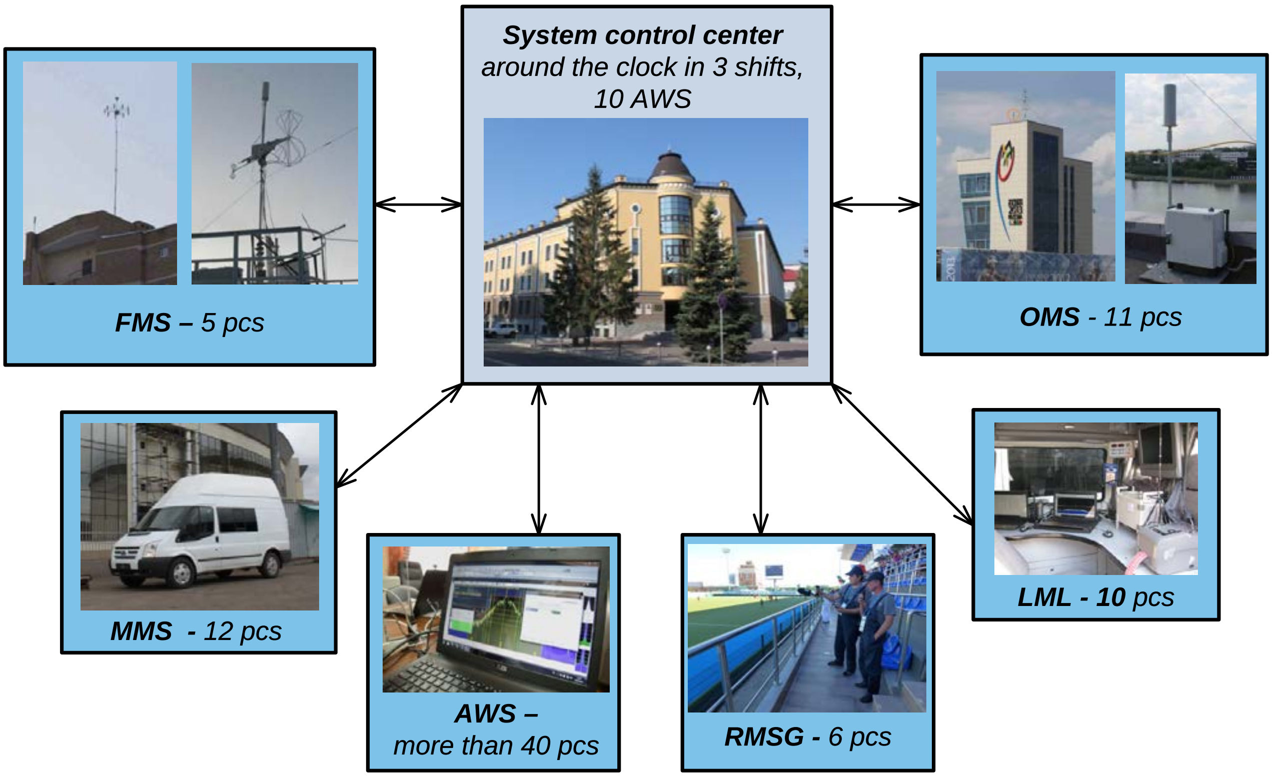

Figure 1. Components of Universiade 2013 ASMMS

The system provides various options to control the equipment. Tasks can be assigned from a control center, from an automated workstation (AWS) of attended stations or radio monitoring systems. It's also possible to control from any PC connected to the system, for example from AWS of an interacting government agency. Encryption is used to ensure security of the data that circulate in the system including its local networks.

Essential software element is a database (DB), which is included in the software at all nodes. The DB is designed to record data about applicants, radio frequencies and radio-electronic equipment, as well as infrastructure facilities, radio monitoring equipment and radio monitoring data. DB makes possible to visualize the data, to generate reports, to send data to other information systems, etc.

Engineering and technical infrastructure includes communication lines and data transmission nodes, service radio communication system, data transmission equipment, server equipment, engineering structures, etc.

Measures used to manage spectrum during Kazan Universiade preparation and holding were divided into three control levels, namely city, zone and object levels.

City level uses a network of five remotely controlled FMS, it provided direction finding, localization and measurement of radio signal parameters.

Zonal level consists of twelve mobile monitoring stations. It provided direction finding, localization and measurement of radio signal parameters, including low-power sources. Location of Universiade sports facilities (orange flags) and the borders of three radio monitoring zones (the fourth zone includes shooting range located outside of the city) are shown in Figure 2. There were up to two crews with MMS and also RMSG with portable equipment in each zone simultaneously.

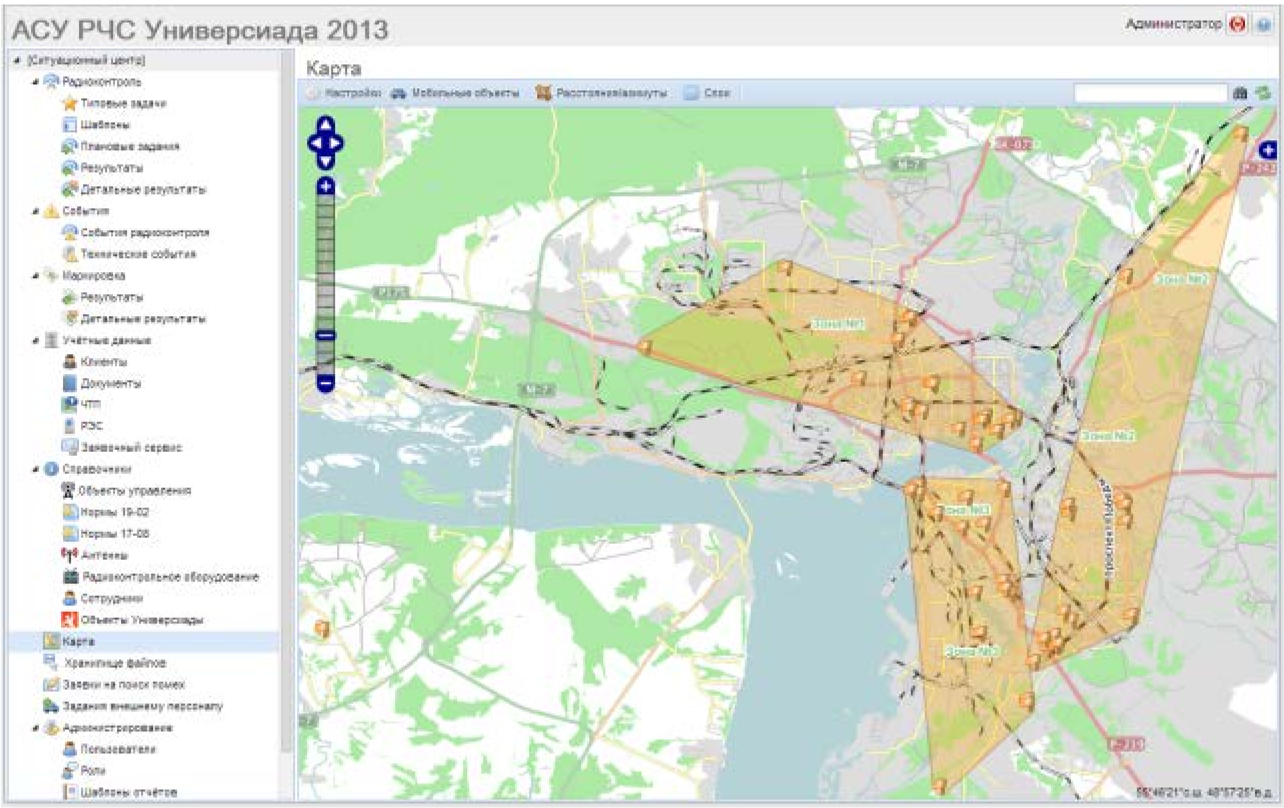

Figure 2. Universiade objects and radio monitoring zones

In order to provide site (local) level of radio monitoring eleven OMS and six RMSG were used, these groups had portable radio monitoring facilities that made it possible to search and localize noise sources in the most hard-to-reach places. The main work on frequency band monitoring was executed at site level in automatic mode with the use of radio monitoring events. OMS scanned the most important frequency bands around the clock, if radio sources not recorded in ASMMS accounting DB appeared then a notification on a radio monitoring event at the particular object was generated at an operator workstation, and then based on decision of system control center (SCS) operations duty unregistered sources of radiation were searched and localized.

ASMMS staff was integrated into operational control center which consisted of the staff of the SCS and external staff (LML, MMS and RMSG crews).

Ten operator workstations were deployed in the SCS. They were used to manage OMS, FMS, MMS, RMSG, special transport and service radio communication system.

SCS management subsystem included a set of central DB server equipment, employee AWS, videowall, audio conference equipment and video conferencing equipment. Server equipment consisted of three servers, two of them were clustered. The third server was intended for storage of backup system data copies. Figure 3 illustrates the operation of the duty shift in the SCS and server equipment system is shown in Figure 4.

Figure 3. Operation of duty shift work in the system control center

Figure 4. Server equipment of the system control center

Communication and data subsystem provided data exchange within the control center and with external nodes that were system management objects. Network equipment provided operation from two Internet providers (one of them provided the main communication channel and the other provided the backup data channel) with automatic switchover in case of loss and recovery of the main communication channel. The communication subsystem also included a server that managed the operation of service radio communication network deployed on the basis of MOTOTRBO digital communication platform. Service radio communication network had three repeaters (Figure 5 and Figure 6) that provided radio communications in all areas of the city and forty eight subscriber stations.

Figure 5. Antennas of service radio communications repeater on a telecommunications tower

Figure 6. Equipment of service radio communications repeater

Remote workstations were deployed outside the SCS in MMS, LML, RMSG, Universiade Directorate, as well as in security service agencies; more than 40 AWS were used. Remote workstations supported all features of operations in the system. Backup control channels were used, if wired channels would fail then automatic switchover to wireless 3G channels occurred.

Use of radio monitoring equipment

When Universiade 2013 ASMMS was deployed, we took into account that radioelectronic enviroment in Kazan during Universiade preparation and holding would be characterized by a significant increase in the number of operating REM, and that the most of the sources would operate in the upper part of the VHF band, in all UHF band and also in the lower part of the SHF range. Substantial part of the sources would have low emission power and, consequently, a small area of the electromagnetic availability, they would be located inside sports facilities, use a broadband modulation and packet data communications. Other factor that was taken into account was a large number of competitive, training and other Universiade objects scattered throughout the city and beyond it, where we should provide EMC of operating radio-electronic equipment and prevent interference. Further experience received during Universiade preparation and holding completely confirmed the correctness of these assumptions. The features of radio monitoring equipment use are explained in Figure 7.

During the Universiade we used two types of fixed equipment: FMS with antenna systems located on the roofs of tall buildings and OMS installed directly at Universiade objects. We also used MMS and portable equipment which was used to equip RMSG.

Figure 7. Features of radio monitoring equipment use

Figure 8 shows the location of fixed radio monitoring equipment when the Universiade was prepared and held. After the end of the Universiade OMS concentration in the city became excessive, therefore most of OMS were moved to other locations for use as measuring stations.

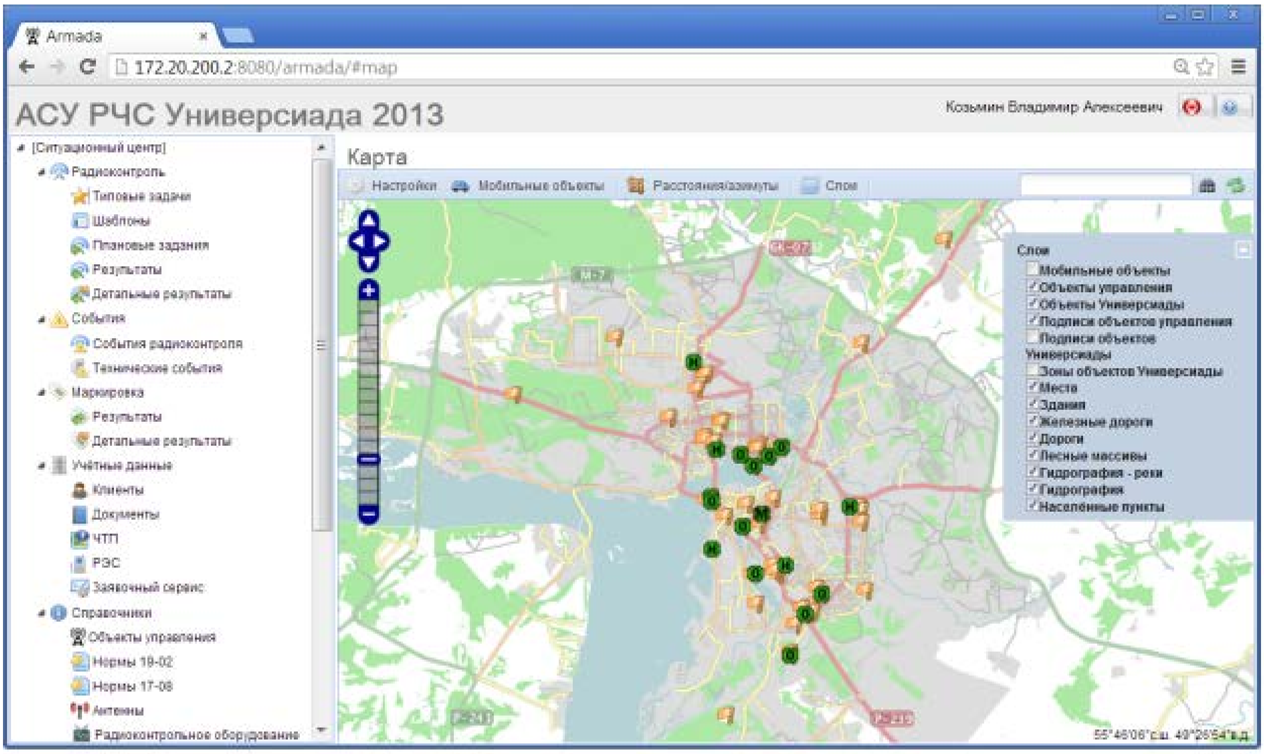

Figure 8. Location of fixed radio monitoring equipment in Kazan city

The main equipment of FMS were ARCHA, ARCHA-I and ARCHA-IN remotely controlled unattended FMS [6].

ARCHA station has ARTIKUL-S Fixed Direction Finder with 3 GHz upper operating frequency, as the sources operating at higher frequencies as a rule have a short range or use directional antennas for transmission and that make fixed direction finders ineffective. At higher frequencies it is advisable to localize the fixed using mobile stations or portable direction finders. Lowest frequency of fixed direction finder is 1.5 MHz; direction finding signals in HF band is execuded using surface waves.

Besides the fixed direction finder, ARCHA-I station has ARGAMAK-IS measuring receiver [7], which provides panoramic and spectral analysis of signals, as well as an analysis of service identifiers and parameters of GSM, UMTS, LTE, CDMA, TETRA, DECT and DVB T/T2/H systems.

ARCHA-IN station has ARTIKUL-S Direction Finder and ARGAMAK-IS Measuring Receiver. All equipment is installed in temperature-controlled waterproof cases; this permits to operate it year-round outdoors without a need of service premises. Figure 9 shows (left to right) signal processing unit of ARTIKUL-S

Direction Finder, direction finder antenna system, UPS that provides operation of station equipment in case of external electric power failure for two hours and receiving and signal processing unit of ARGAMAK-IS Measuring Receiver with external field sensors unit used as a receiving measuring antenna.

Figure 9. ARCHA-IN Station equipment

Figure 10. Meter antenna system (left) and direction finder antenna system (right) on a roof of a residential building

OMS were also based on ARGAMAK-IS Measuring Receiver, they had thermostatic waterproof cases with alarm sensors, signals from them were received in ASMMS. OMS was installed directly in the most important sports facilities and provided round-the-clock monitoring of short range radio-electronic equipment used in the objects, they identified and measured signals in the range from HF to the lower part of SHF range, including signals from television cameras with wireless links, they analyzed service identifiers and parameters of cellular communication systems and wireless access systems. The highest operating frequency of OMS was 8 GHz.

Figure 11 to Figure 14 give two examples of OMS placement.

FMS and OMS equipment was remotely managed from the SCS, and if required they were managed from mobile stations or radio monitoring groups. The control was provided via a wired communication channel, it was backed up by 3G wireless channel, as well as by radio channel for transmission of alarm messages based on deployed MOTOTRBO service radio network.

Figure 11. Rowing Sports Center (the orange circle shows OMS antenna)

Figure 12. OMS located on the roof of Rowing Sports Center

Figure 13. OMS located in Kazan Arena stadium (orange circle shows antenna of MOTOTRBO emergency channel system)

Figure 14. OMS antenna located inside Kazan Arena stadium

Mobile equipment was used for radio monitoring operations if low power of transmitters, high directivity of transmitting antennas and the distance from the radio source made it difficult or impossible to make measurements and localize the sources using fixed equipment.

ARGUMENT-I Mobile Stations and MMS of other types, such as BARS MPI, BARS-VCH were used as mobile stations at the Universiade. All MMS could be integrated with ASMMS, but direct control of RME was implemented only for ARGUMENT-I Stations. These stations provided measurement of radio signals up to 43 GHz and automatic direction finding within 1.5 to 8000 GHz range. A mobile station on duty at a sports venue is shown in Figure 15 and operator's workstation in the station is shown in Figure 16. In order to extend monitoring and amplitude direction finding range up to 43 GHz, as well as for operation as LML, the station had ADVANTEST spectrum analyzer integrated in ASMMS and also P6-69 measuring antenna.

Data exchange between the mobile station and ASMMS was provided via 3G modem wireless channel. Also during the preparatory period all main competition places were equipped with special places for wired connection of MMS to the Internet, so during parking near such sites wired connection over Ethernet cable was used.

Figure 15. ARGUMENT-I mobile station on duty near a sports venue

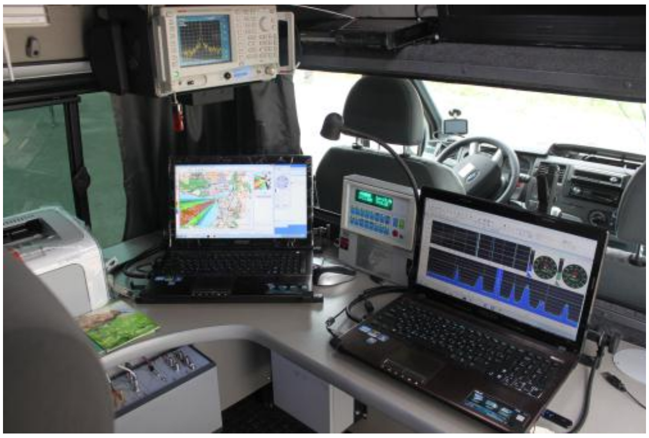

Figure 16. Operator's workstation in the mobile station

Portable equipment was used by RMSG in hard-to-reach places: on the roofs of tall buildings, indoors, including Universiade sports venues. ARC RP3M Handheld Direction Finders and PR100 handheld receivers with a set of directional antennas were used as portable equipment. A working moment of localizing an interference source in a sports facility is shown in Figure 17 and work of direction finding group in a special tent at a stadium during a rugby match is shown in Figure 18.

Figure 17. Radio monitoring group during search of an interference source in a stadium

Figure 18. Monitoring of electromagnetic environment by radio monitoring control group in the stadium. ARC-RP3M Handheld Direction Finder is used as radio monitoring equipment

Features of software use

SMO Armada software package forms the basis of ASMMS, it has the following functional subsystems:

- Application service
- Radio-electronic equipment testing and labeling
- Planned mode
- Online mode
- Assignment of tasks to external staff
- Accounting data
- Reference data
- Status monitoring
- Mapping
- Report generation

- Administration

Application service was designed for automated processing of application for the use of radio-electronic equipment. Universiade information portal had a service that permitted portal users to send an application for the use of radio-electronic equipment. The applications were automatically submitted to ASMMS DB where they received Accepted status. Experts of Universiade Directorate used ASMMS AWS that was located in Universiade Village preprocessed the applications received and made a decision: to reject the application and to notify the applicant or to continue processing. If the application was approved then it was assigned Under consideration status.

All application with Under consideration status were processed by specialists of radio frequencies department using AWS located in SCS. Based on the results of processing the application is rejected with immediate notification of Directorate employees or they were entered in the database with Planned status, this was accompanied by allocating time-frequency resource for radio-electronic means specified in the application in declared sports facilities. For such applications after their evaluation by Universiade Directorate experts and possible improvement, Guidelines and Conditions of REM Use electronic document was generated that gave the applicants the right to go through REM testing and labeling procedure.

Application processing sequence is shown in Figure 19.

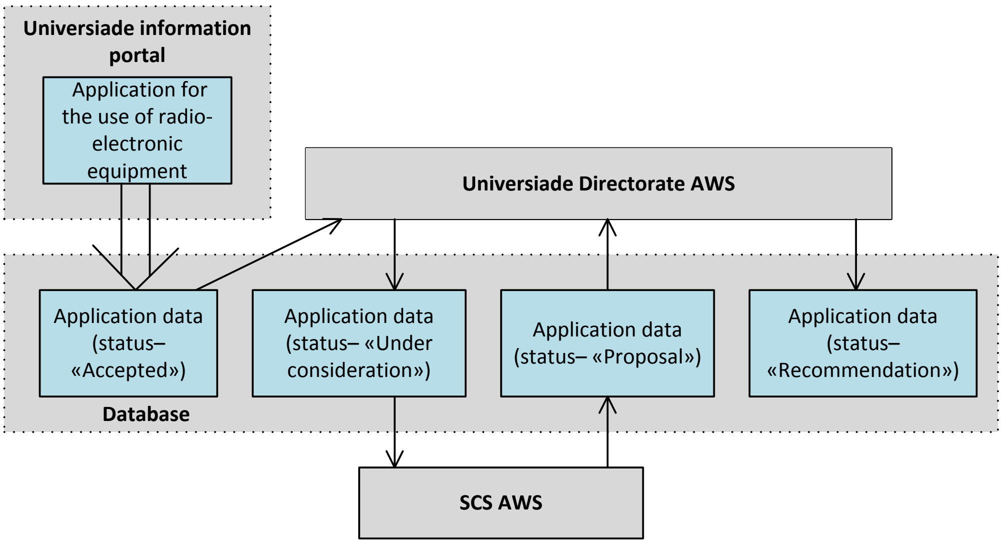

Figure 19. Processing of REM usage application

RES testing and labeling subsystem was used for technical verification of radio-electronic equipment parameters compliance with Recommendations on REM Use Conditions and labeling the REM with a colored sticker. Testing included checking that actual REM emissions specifications (frequency, bandwidth and level) comply with issued recommendations. A decision to label the REM was taken in automatic mode based on the results of the measurements. Testing and labeling were executed in labeling and measuring laboratories that were deployed on the basis of fixed and mobile stations. Local LML database was automatically synchronized with the central ASMMS database via data networks, as shown in Figure 20, and LML operation was provided both when the communication channels operate and when they failed.

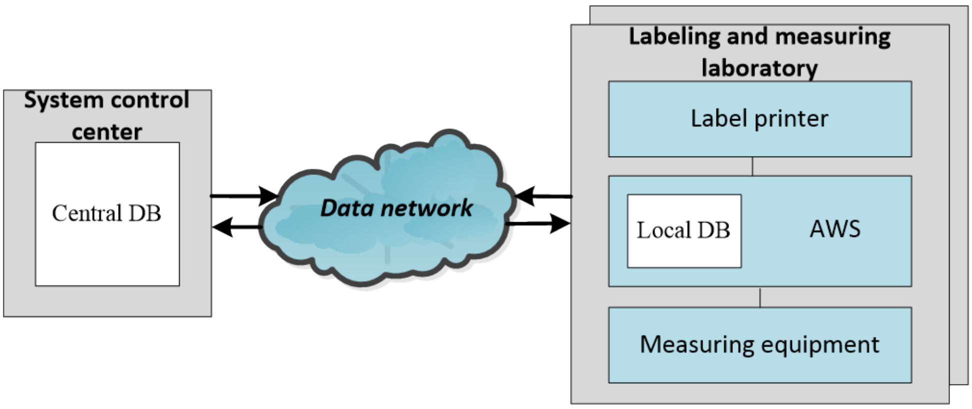

Figure 20. Interaction between LML and system control center database

Before testing, REM user submitted the number of issued recommendation. Based on this number a list of frequencies is displayed in LML employee AWS that subject to verification. During testing measurement results for frequency bandwidth and frequency were compared with bandwidth tolerances in automatic mode and a decision about the possibility of REM operation in accordance with Guidelines requirements. REM testing and labeling algorithm is given in Figure 21 and Figure 22 shows a production still when LML employees check the parameters of a mobile television station.

If a positive decision was taken on test results then a marking label was printed and the status of frequency assignments in the database was changed to “Effective”. The labels were pasted to REM and they permitted to identify it uniquely. Labels were used as seals, i. e. when one tries to remove or peel the label then it was destroyed. The label contained object number or object group at the Universiade, the area where it was permitted to use the REM, the period of authorized REM use and REM identifier in the database. An example of the label is given in Figure 23.

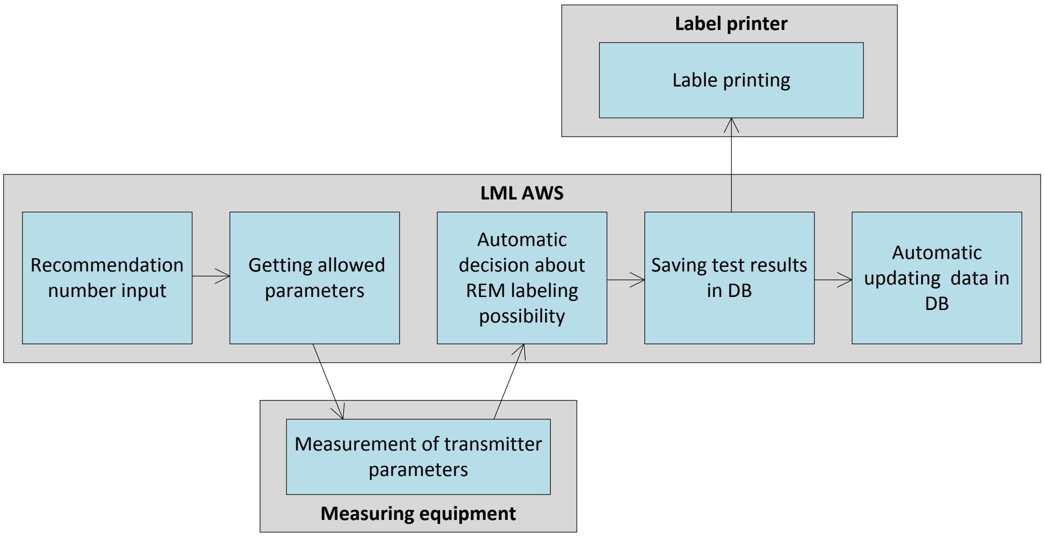

Figure 21. Radio-electronic equipment testing and labeling algorithm

Figure 22. Checking parameters satellite transmitter mobile television station

Figure 23. An example of identification label

Testing and labeling subsystem permitted to put bar codes on the labels, the bar code contained all required data in encrypted form. Based on the results of reading barcodes by scanners at incoming control terminals it was possible to monitor REM that were carried to sport venues. However, as there were many objects of the

Universiade and a large number of incoming control terminals that required to train many employees, this ASMMS function was not used in Kazan.

Planned mode subsystem provided automatic solution of radio monitoring tasks based on a given plan (schedule), including measurement of signal parameters, localization of radio sources, discovery of new sources, monitoring the emissions of registered REM and their comparison with the standards, measuring of frequency and frequency band occupancy, etc. The use of a flexible radio monitoring events system that used spectral and temporal masks in the automatic mode was of particular importance. This made it possible to operate radio monitoring equipment in automatic mode to detect interference and search deviations of REM emission parameters.

During Universiade preparation and holding “protected” ranges were monitored, i.e. the ranges of REM the users admitted to the object that were registered by Universiade Directorate, as well as REM ranges of emergency and socially significant services, this monitoring was based on the tasks with generation of radio monitoring events.

A special feature of automatic task execution subsystem is its ability to simultaneously manage a large amount of equipment, as well as execution of the tasks by the equipment in stand-by mode if communication channels fails. When the subsystem operates in standby mode, the results of task execution stored in local control servers deployed in equipment management controllers. The results of task execution were sent to the central database in automatic mode when communication channels were restored.

Options for displaying the results of planned tasks execution in ASMMS interface are given in Figure 24 and Figure 25.

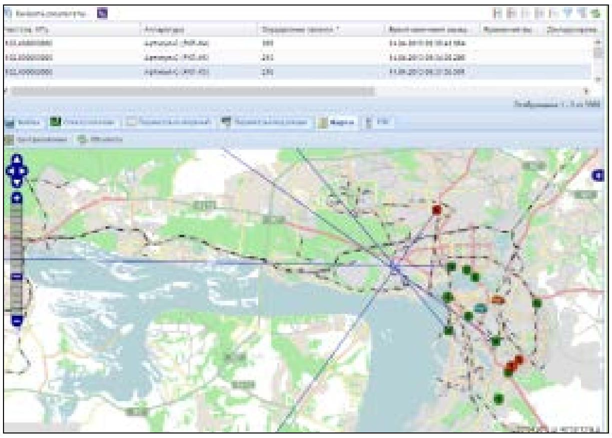

Figure 24. Display of direction finding results on the map

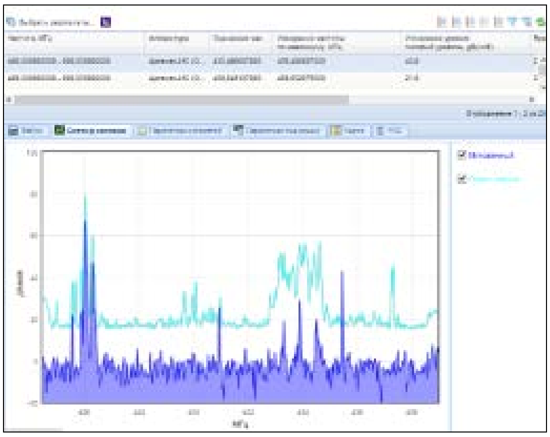

Figure 25. Detection of a signal based on radio monitoring event (the signal level is higher than the mask)

Online mode was used when it was required to take the necessary decisions in complex cases of interference source search and for immediate localization of emission sources. In online mode, the operator directly managed required radio monitoring (RM) equipment group in real-time. In online mode, simultaneous synchronous or asynchronous control of multiple direction finders and radio receivers were managed and the accounting data database was accessed.

In fact, all fixed radio monitoring equipment executed tasks automatically using radio monitoring events during the Universiade. If an event occurred, such as emergence of a signal with level higher than the spectral mask, then SCS operator received a message, and he switched to online mode for detailed analysis of what was happening in order to clarify hazard degree of the event and to take a necessary decision.

Examples of online mode screenshots are given in Figure 26 to Figure 29.

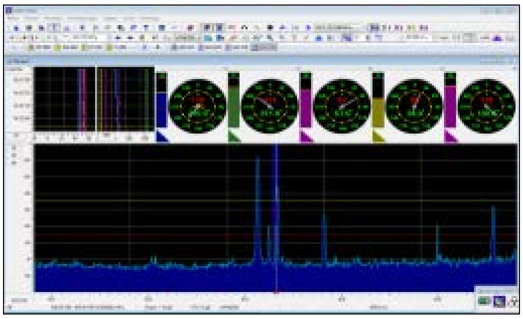

Figure 26. Direction finding of a radio emission source. Five fixed direction finders are used

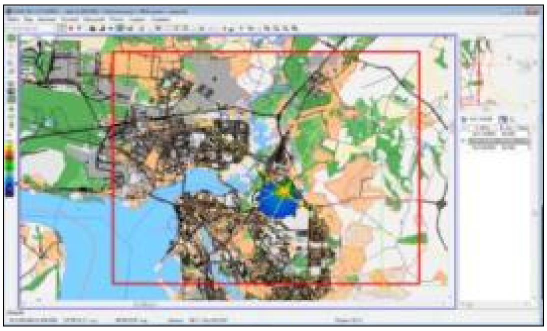

Figure 27. Localizing the source of radio emission on the map

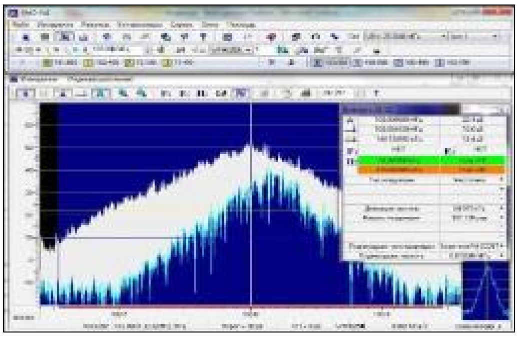

Figure 28. Occupied bandwidth and central frequency of the signal are measured

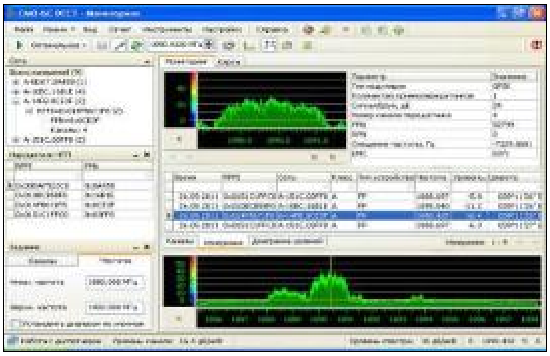

Figure 29. Parameters of DECT base station are measured

Subsystem for assignment of tasks for external staff arranged the operation of MMS, RMSG and LML. Subsystem for assignment of tasks for external staff assigned targeted tasks to the crews, monitored their execution and saved the results. The tasks were assigned both based on a plan, for example, according the schedule of sports events for the next day, and off-plan, for example, tasks for interference search if they were detected or tasks for received application. An example of ASMMS interface with a task assigned to external personnel is shown in Figure 30.

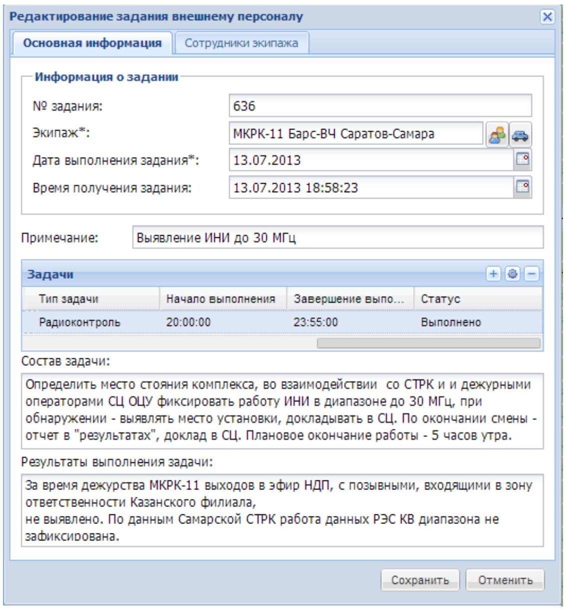

Figure 30. Task assignment to external personnel window

Applications for interference search were received in SCS from Universiade Directorate. If an application was submitted then the Directorate set its priority. There were four applications priorities that determined response time which included time to review the application and to take a decision on the need to send forces and means to localize the interference source. For application with the highest priority the response time was 10 minutes.

The applications for interference search were registered in ASMMS, the decisions on the allocation of the forces and means and the results were also recorded there.

Accounting data subsystem was intended to store frequency assignments, REM, contractors, to account permits and radio emitters present in the air that do not have (do not require) permits. The subsystem provided the use of accounting data to generate plan tasks and display user data samples on the electronic area map.

Reference data subsystem was used to store data on equipment used in process control, as well as data on the employees, on the standards for deviation of bandwidth and frequency and to map reference data on the electronic area map. Examples of reference data windows are given in Figure 31.

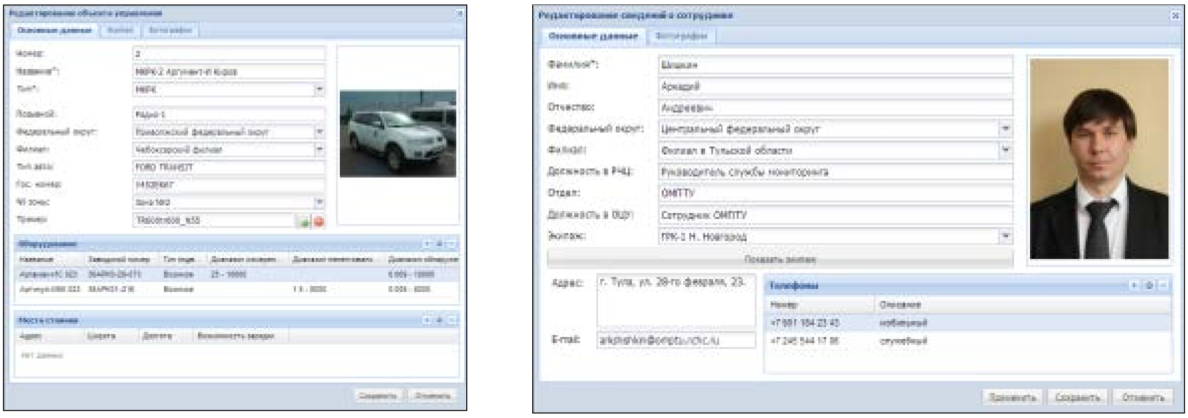

Figure 31. Examples of reference data windows

The subsystem provided accounting of the employees, radio monitoring centers, RM equipment, it was also used to set radio monitoring tasks for selected equipment.

Status monitoring subsystem provided control of the current state of communication channels, equipment health and automatic fault diagnosis. It also supported a large list of technical events that notified employees about change of the current status of the system elements, including:

- Triggering the alarm system in ASMMS
- Communication channel switchover
- Switchover of primary and secondary power supply sources
- Permissible threshold crossover for currents, voltages and operating temperatures.

Electronic area map displayed the current location and condition of ASMMS mobile elements. If required, the map displayed information on technical events in radio monitoring stations.

Mapping subsystem provided geographic information support for its work, including:

- Graphical display of data on the electronic area map
- Selection of geographic coordinate system
- Display of selected map, information and user layers
- Measurement of distances and angles

- Search of map objects
- Display of key information about selected map or information object
- Display of mobile object tracks for any time period

Reporting subsystem permitted to create reports on selected data groups using specified presentation templates. The reports could contain particular data, tables, graphs and charts, including geospatial data. The reports could be generated in various formats (docx, xlsx, html, pdf) from a single template and the users could quickly edit the templates.

Administration subsystem was intended to manage user accounts: to add new users, edit, deactivate or delete existing user accounts, as well as to differentiate users access rights to the system and data editing.

System deployment stages

Work on Universiade 2013 ASMMS deployment were based on a plan of measures to provide spectrum management during preparation and holding XXVII World Summer Universiade 2013 in Kazan approved by the head of Roskomnadzor of Russian Federation in September 2010. Based on this plan, radio frequency service of Volga Federal District developed request for proposal and a contest was held where IRCOS was chosen as a developer, supplier and integrator of ASMMS.

ASMMS was commissioned in several stages, as it is shown in Figure 32. At the first stage, in April 2012 a pilot equipment batch (two OMS and one FMS) was delivered together with beta version of the system software, SCS and facilities were prepared for radio monitoring equipment. During the pilot work on the system the correctness of decisions was verified, necessary software improvements were made and identified errors were corrected.

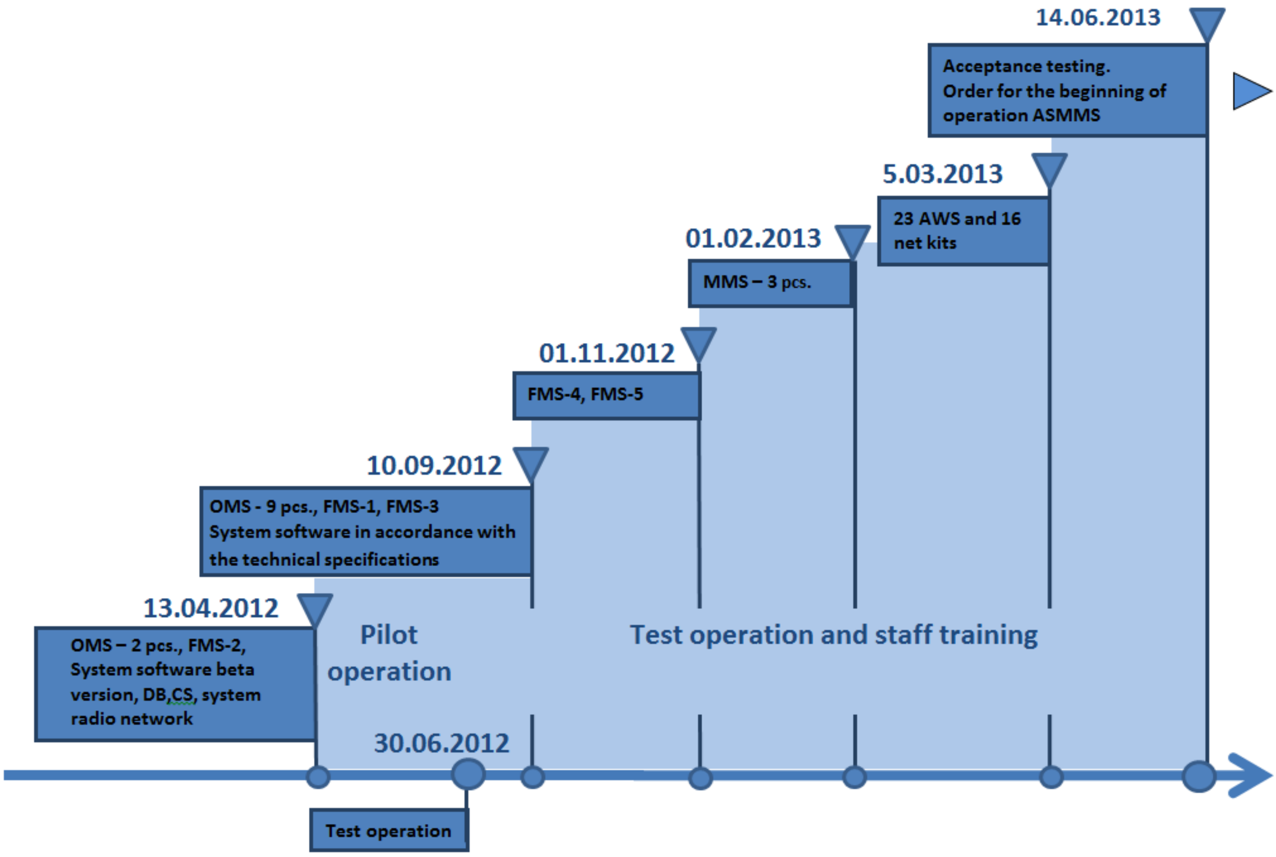

Figure 32. System deployment stages

The second stage of system deployment began in July 2012 and after interim acceptance testing of the system its test operation began.

During test operation the employees was trained, additional equipment was delivered, installed at the Universiade sites and the software was improved. In late April 2013 acceptance testing of the system began, which lasted about six weeks. Such long test term was due to ASMMS complexity, its versatility, and all personnel and top-level managers had to take part in the testing. In mid-June 2013 acceptance tests were successfully completed and Universiade 2013 ASMMS system was commissioned.

Conclusion

Universiade 2013 ASMMS provided remote control of geographically remote fixed, mobile and handheld radio monitoring means, testing and marking of radio-electronic means, interaction with external information structures when Summer Universiade in Kazan was prepared and held. The system enabled effective personnel management, coordinated task assignment, control of their execution and necessary decisions in real time.

With the help of application service subsystem during preparation and holding the Universiade 285 applications for the use of REM were received, 39 of them were rejected. Ten LML (two fixed LML and eight mobile ones) were deployed in order to test REM. In total, 8368 REM were tested and labeled, including 6714 land mobile service REM, 1364 short-range devices, 20 fixed satellite service REM, 266 fixed service REM and 4 radio location service REM.

During twelve days of the Universiade employees of radio-frequency service detected 207 violations of frequency use, the main ones were: operation of radio microphones, so-called “radio ear” devices, earth satellite stations providing broadcasting of Universiade events that did not undergo testing and labeling procedure and deviation of radiation parameters of mobile REM of opening ceremony organizers.

The experience of using Universiade 2013 ASMMS was used by radio frequency service of the Russian Federation at XXII Olympic Winter Games 2014 in Sochi.

This article can be used as a basis for additions to ITU-R SM.2257-1 Report [2] developed to help communications administrations to manage frequency spectrum during organization of international events.

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