Present Status and Future Developments of the Russian Radionavigation System Chayka and Joint Chayka/Loran-C Radionavigation Chains

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The equipment of the Chayka stations is under modernization aimed at implementation of the ground-based segment of the integrated radionavigation system Chayka/GNSS. Combined radionavigation systems Chayka-Loran-C are being developed. Experimental and field trials confirmed the benefits from including the Ussurijsk Chayka station into the Korea-Japan-Russia Chayka/Loran-C chain. Implementation of the joint Russia-Japan Chayka/Loran-C chain is hampered because of the problem of making closer signal shapes of the Tokatibuto station and Chayka. The problem can be bypassed if Tokatibuto is incorporated as another secondary into the Russian-American Chayka/Loran-C chain.

The Pulse-Phase Radionavigation System "Chayka" is important aid to navigation providing fixes in European Russia, Ukraine, Byelorussia, west part of Northern Route and northwestern Pacific.

"Chayka" system consists of 14 stationary transmitting stations operating in four national chains. Two stations – Petropavlovsk and Alexandrovsk operate also in Russian-American Joint Chayka/Loran-C chain.

Russian "Chayka" stations equipment modernization is going on. The purposes and directions of this upgrade are close to eLoran. The process of modernization will be resulted in creation of terrestrial part of integrated radionavigation system "Chayka/GNSS".

The first direction of modernization is installation of new synchronization and control equipment. New equipment is installed at three big stations of East Chain and two stations of European chain. Till 2011 all stations will be equipped with new synchronizers and GNSS reference stations. Time scales and times of transmission of PPRNS radio pulses will be bounded to GNSS time scale.

The method of direct TOT control at Master and Slave stations sufficiently increases the accuracy of synchronization especially during the nighttime at long baselines when skywave level is high. To confirm this advantage in May 2008 at Ussuriysk station an experimental GNSS time scale synchronization device has been installed. The measurements proved high accuracy of emission delay maintenance both in Russian East Chain and in Korean-Japanese-Russian Joint Chain. The station is ready to operate in joint chain.

Another feature of new equipment is transmission of DGNSS corrections in Eurofix or Chayka/GNSS format. PPRNS differential corrections transmission is also under consideration. In 2009 Petrozavodsk station of European Chain starts the experimental transmission in Chayka/GNSS format.

The second direction of modernization is transmitter improvement. It includes replacement of old final-stage glass thyratrones with metal-ceramic ones and replacement of old thyratrones driving circuits with solid-state ones to increase reliability and timing precision. Transmitter

modernization is completed at all Russian Chayka stations. There are plans to modernize Ukrainian and Byelorussian stations of European chain using the same equipment.

In parallel with existing stations modernization the set of equipment for new stations was developed and tested. New station equipment is placed in containers and includes solid-state transmitter, synchronization equipment and GNSS reference station.

New Loran-C/Chayka/GNSS synchronization and data transmission technologies require new user and control equipment. New Loran-C/Chayka/GNSS receiver will provide Time of Arrival (TOA) measurements for each station in view sufficiently increasing coverage areas of PPRNS chains. Multi-format DGNSS decoding will be also implemented.

To reproduce big variety of data channels and signal conditions in user equipment tests new PPRNS imitator was developed. The main idea of this device is hardware minimization. All main tasks are performed by PC, which allows new features implementation by software revision only. The last version imitator can reproduce any pulse shape, ECD, skywave, atmospheric noise, sine and cross-rate interferences, differential signal level, Eurofix and Chayka/GNSS data channels. Motion imitation and Loran-C Data Channel will be implemented soon.

Another piece of control equipment under development is research receiver for ASF, ECD and other pulse parameters precise measurements.

Initial tests of differential Chayka subsystem were carried out in March 2009. Corrections were sent from Petrozavodsk station in Eurofix-like format. 2-DRMS accuracy measured near the reference station in St. Petersburg appeared to be better than 20 meters.

Modernization of transmitting stations provides necessary base for joint Chayka/Loran-C chains. According to international agreements, there are two projects of joint chains in Far East area and one in Northern Europe. Korean-Japanese-Russian chain includes Russian station Ussuriysk as additional slave in East Asia chain. Another project is Russian-Japanese chain where Japanese station Tokatibuto is included as additional slave in Russian East chain.

Main problem in joint chains is the difference of Chayka and Loran-C pulse shapes. This problem and its solution were found 20 years ago. It appeared that fronts of Chayka and Loran-C pulses are very close one of these pulses being inverted. The idea of inversion is implemented in Russian-American chain so it will be in Korean-Japanese-Russian too. Ussuriysk station will transmit normal Chayka pulses in Russian chain and inverted Chayka pulses in joint chain. The measurements in May 2008 gave the following results: ECD<0.25 mks, Ensemble Toleranse of eight first half waves <0.009. These values meet "Specification of the transmitted Loran-C signal" and provide reliable operation of Loran-C receivers, which was also proved by laboratory and field tests. Predicted coverage area of joint chain is shown at Fig.1. The area increases more than twice with Ussuriysk as additional slave.

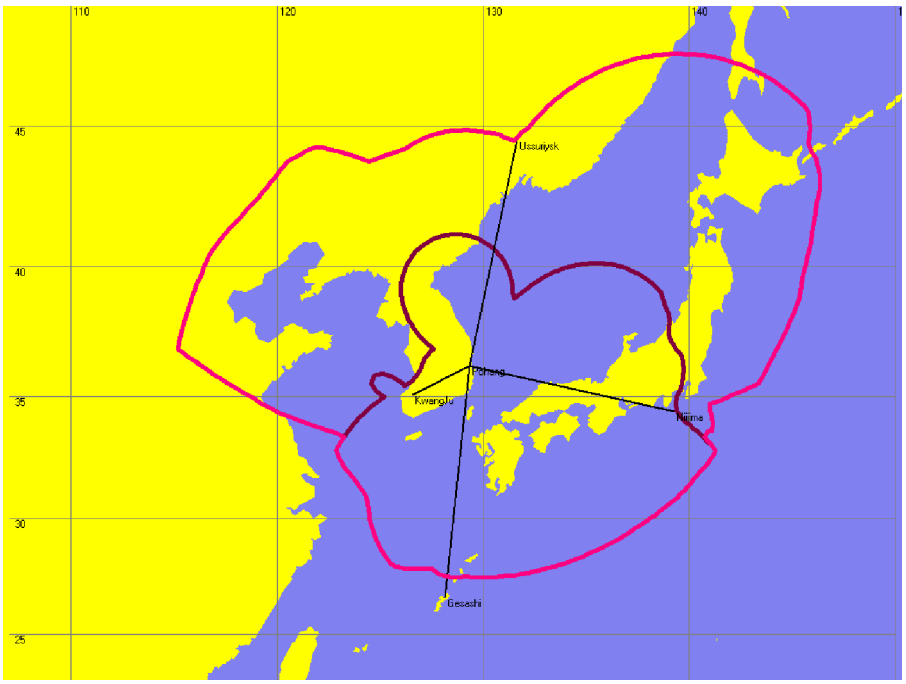

Fig.1. Predicted coverage area of Korean-Japanese-Russian joint chain

Establishing of Russian-Japanese joint chain can considerably increase coverage area of Russian East chain in the case of close pulse shapes (Fig.2). It could be done either by inverting Tokatibuto signal or by inverting all four Russian stations signals. In the first case pulse shapes of all stations of joint chain are close to Chayka pulse shape, in the second case – to Loran-C. The expansion of coverage area can be realized only by user equipment adapted to the pulse shape used in joint chain. For user equipment not adapted to this shape coverage area is not expanded but reduced.

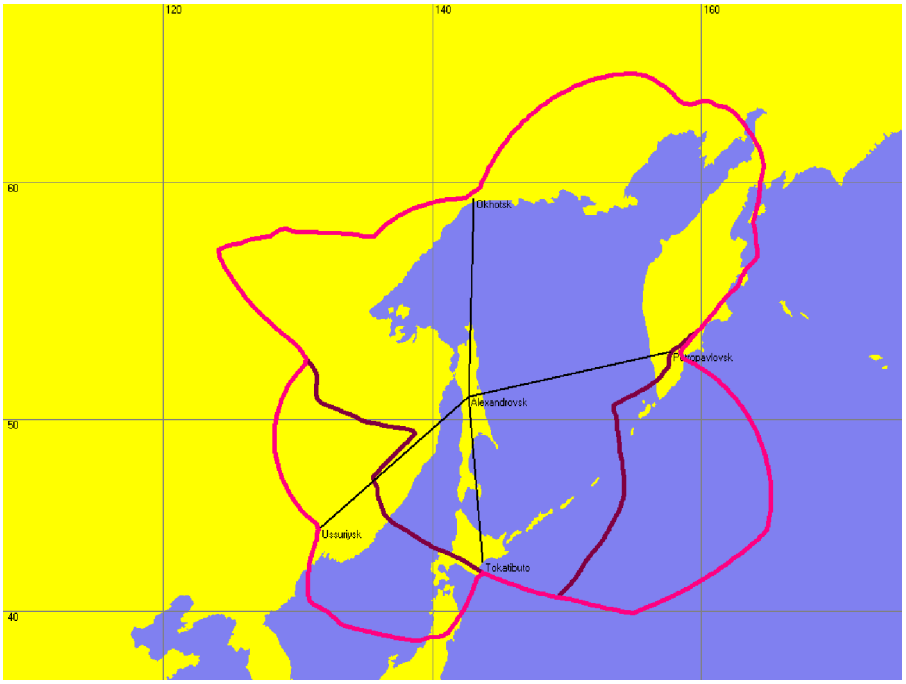

Fig.2. Predicted coverage area of Russian-Japanese joint chain.

Some Chayka receivers are not adapted to Loran-C signals and some Loran-C receivers are not adapted to Chayka signals. This is why Russia is interested in Tokatibuto inversion but Japan is

interested in four Russian stations inversion. Including Tokatibuto in Russian-American chain could solve this contradiction. In Russian-American chain, Tokatibuto can transmit standard Loran-C signals as Attu does while Russian stations Petropavlovsk and Alexandrovsk transmit inverted Chayka pulses. Predicted coverage area of existing Russian-American chain and its expansion with Tokatibuto are shown at Fig 3. Comparing Fig.2 and Fig.3 one can see almost the same expansion of coverage areas. The idea of Russian-American-Japanese chain needs further treatment.

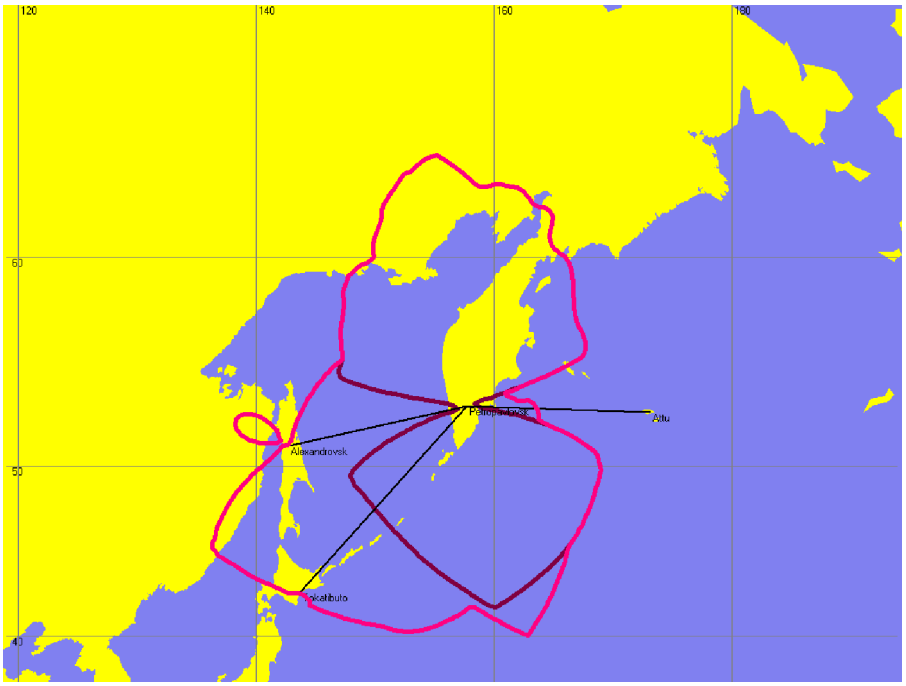

Fig.2. Predicted coverage area of hypothetical Russian-American-Japanese joint chain.

In Northern Europe some expansion of coverage areas is expected by establishing Norwegian-Russian joint chain (Fig.4).

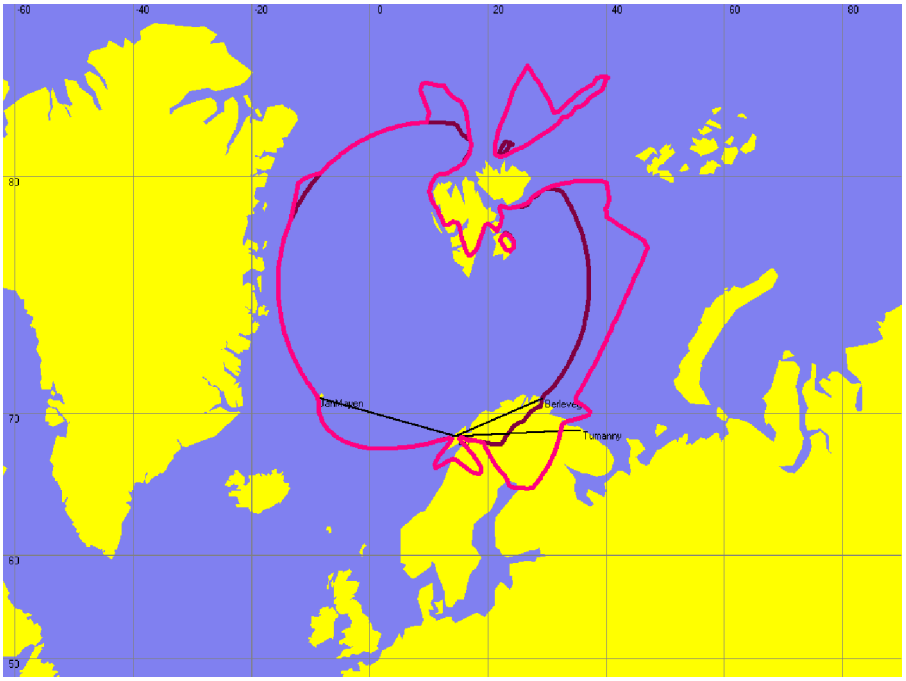

Fig.4. Predicted coverage area of Norwegian-Russian joint chain.

This chain includes Russian station Tumanny as additional slave in Bo chain. Tumanny station pulse shape in joint chain will be close to Loran-C. Main problem of this joint chain is very bad wave propagation between Bo and Tumanny. Taking into account these conditions two methods of emission delay maintenance has been proposed. Fist method uses signals of Berlevag slave station located much closer to Tumanny. Second method uses direct TOT control. Taking into account plans of modern synchronization equipment installation in 2008-2009 this method is preferable.