

# 5G base station prototyping: implementation possibilities in Russia

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**Abstract.** A brief overview of the development of 5G mobile communications in the world and in Russia is presented. 5G pilot projects in Russia are considered. The basic requirements for 5G networks, the tasks facing developers, examples of hardware and brief technical specifications of hardware produced in Russia that can be used to create base station equipment for 5G networks are given. The work of MIET on the development of software and algorithmic support for 5G transceiver equipment is described. An estimation is given concerning the feasibility of implementing 5G generation mobile communication base stations in Russia, including on the basis of hardware from Russian manufacturers.

## 1 Introduction

Currently, mobile operators are actively working on testing and implementing the fifth generation (5G) mobile communications equipment (IMT-2020 standard). The concept of creating and developing 5G/IMT-2020 networks in Russian Federation was included in the national program “Digital Economy of Russian Federation”. In accordance with the program passport [1] from 12/24/2018, the radio frequency bands for creating 5G radio communication networks should be determined in Russia and a draft for radio frequency release roadmap for the implementation of 5G/IMT-2020 should be developed until 09/30/2019. The concept of constructing narrow-band wireless communication networks “Internet of things” in Russian Federation was approved on March 29, 2019 [2]. Implementation of pilot projects in five sectors of the economy is planned until 12/31/2020. The National Center for Informatization of Rostec State Corporation was chosen as the roadmap operator for the development of 5G wireless technology and industrial Internet of things (IoT) for the time period until 2024 [3].

## 2 5G Implementation review

### 2.1 5G Worldwide

Many open sources [4] describe the projects of foreign companies related to IMT-2020 technologies. For example, in 2019, T-Mobile Poland launched a 5G network in the center

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of Warsaw. Telia has complemented the launch of a 5G network fragment in Sweden with the launch of a 5G network fragment in Tallinn. Telenor Norway will launch a new pilot project based on Ericsson; Huawei and Turkcell have introduced a 5G-oriented core network project for the cloud; Vodafone announces the launch of 5G tests in Manchester, Verizon launches 5G in Chicago and Minneapolis, ZTE Corporation and Qualcomm Technologies, Inc. jointly demonstrated 5G network services based on an integrated commercial sub-6 GHz system. In South Korea, 12 thousand 5G base stations (BS) were installed. By mid-2019, LG Uplus plans to install another 50 thousand base stations. Shanghai has become a region where there is both 5G coverage and a gigabit broadband data network. NTT DoCoMo, KDDI, Softbank, Rakuten received 5G licenses in Japan; Swisscom and Ericsson launched the first 5G network in Europe with mobility support on 04/17/2019.

And this is only a part of the total data on the implementation of 5G in the world. Some countries already have significant 5G network coverage areas, and all major operators are installing new generation BSs. Similar trends are observed in Russia.

## 2.2 5G in Russia

Open sources of the Internet published information on pilot projects being implemented in Russia. Rostelecom completed testing of the 5G network in Innopolis, which has been running since the autumn of 2018 on Huawei equipment. Tests showed a bandwidth of up to 2.1 Gbit/s per sector and delays of the order of 1-3 ms [5]. Rostelecom also conducted tests in Skolkovo on the basis of Nokia equipment and in the Hermitage in St. Petersburg on the basis of Ericsson technologies. Mobile operators conducted 5G tests during the 2018 World Cup on the basis of foreign equipment, in Kazan - MegaFon using Nokia, Tele2 and MTS equipment - using Ericsson equipment. Ericsson AIR 6468 base stations were installed in Moscow, St. Petersburg, Kazan, Rostov-on-Don, etc.

At the The State Commission for Radio Frequencies meeting [6], the results of studies on the use of the 3400-3800 MHz radio frequency band by MegaFon and Rostelecom were examined. It has been determined that the electromagnetic compatibility of mobile communication network equipment of 5G communication networks with communication equipment of existing radio services is not provided; therefore it is required to estimate the feasibility and cost of conversion and redistribution of the radio frequency spectrum. The Ministry of Communications of Russia will prepare a draft plan for the conversion of the radio frequency spectrum in the interests of introducing 5G technology and determining the possibility and conditions for using the corresponding frequency ranges.

For the World Winter Universiade 2019 in Krasnoyarsk, the State Commission for Radio Frequencies allowed to use radio frequency bands in the range 5150-5725 MHz.

By the decision of the State Committee for Radio Frequencies on 24/12/2018, for the creation of pilot zones, the radio frequency bands 4800-4990 MHz and 27.1-27.5 GHz were allocated in a number of territories, including Derbent, Yekaterinburg, Kazan, Kaliningrad, Kemerovo, Krasnodar, Moscow, the territory of the "Mikron" plant in Zelenograd and the section of the M-11 highway in the Moscow Region, Skolkovo, Murmansk, St. Petersburg, Sochi, Tomsk, Ulyanovsk, and the Republic of Tatarstan. The application for testing 5G technology can apply to any interested organization. The results of the consideration of applications are planned to be submitted to the State Committee for Radio Frequencies no later than June 1, 2019. In 2020, it's planned to launch a 5G network zone in five regions of Tatarstan.

Thus, the development of mobile networks in Russia has the same pace as that of the leading countries, however, the introduction of 5G is based on the equipment of foreign vendors.

The competence center of the NTI "Wireless Technology and the Internet of Things" in the test area of Russian-made 5G equipment at Skolkovo Innovation Center conducts joint tests with Rostelecom and MegaFon [7]. The main task of the test zone is to become an independent platform for continuous debugging and testing of complex solutions for 5G networks based on equipment of Russian manufacturers.

Any company willing to provide Russian-made telecommunication equipment or related software can take the tests. Solutions for indoor/outdoor 5G networks, for long/middle range communications, high/low user capacity can be tested.

The frequency range used for testing is 4800-4990 MHz. The total output power of the transmitters should not exceed 52 dBm. At the same time, the resources of the Rostelecom and Akado operators are used. Equipment vendors include Russian companies: ELTEKS, Sozvezdie concern, Radio-Gigabit, LLC «RTC – Network Technologies», NPF Mikran. The roadmap for the development of the 5G test zone is designed until 2024. The result should be a solution using radio equipment and the core of a 5G network of Russian production.

### 3 5G Requirements

The following basic requirements are imposed on 5G networks [8]:

- peak data rate of 20 Gbit/s,
- user experienced data rate 100 Mbps,
- spectral efficiency 30 bit/s/Hz,
- latency of the order of 1 ms.

In addition, IMT-2020 networks require network coverage in difficult situations: with high mobility subscribers, in areas with a high population density, multipath propagation due to developed infrastructure. The development of the Internet of Things is leading to demands for an increase in the density of connected devices to 1 million terminals per 1 km<sup>2</sup>. Modern communication networks should provide high reliability, global coverage, low latency with a noticeably increasing amount of transmitted data. In addition, new devices should have less power consumption, and networks should be deployed in a shorter time.

All these requirements correspond to the tasks of the developers. These tasks include increasing the spectral efficiency up to 30 bit/s/Hz, reducing the user plane latency to 1 ms, and constructing highly efficient phased antenna arrays (PAR) with combining frequency ranges and dynamically controlling their directivity characteristics. It should be noticed that in order to achieve a spectral efficiency of 30 bit/s/Hz and a peak BS bandwidth in the down channel of 20 Gbit/s, a band of at least 667 MHz (downlink) and 333 MHz (uplink) is required. Then the total frequency band should be at least 1 GHz. For this reason, preference is often given to the range above 6 GHz.

### 4 Industry possibilities in Russia

It is known, that Russian electronic industry produce devices that can be used to design base station equipment and deploy 5G networks. Among these companies are JSC RDC "ELVEES", JSC "PKK Milander", JSC "VZPP-S", JSC "NPF" Mikran", JSC "MCST" and PJST "INEUM".

Joint-Stock Company Research and Design Center "Electronic Computing Information Systems" (JSC RDC "ELVEES") [9] develops a series of SDR transceivers, that are reprogrammable mixed-signal SoC integrated circuits, intended for use in telecommunication equipment and phased antenna arrays. The 1288XK1T system on chip

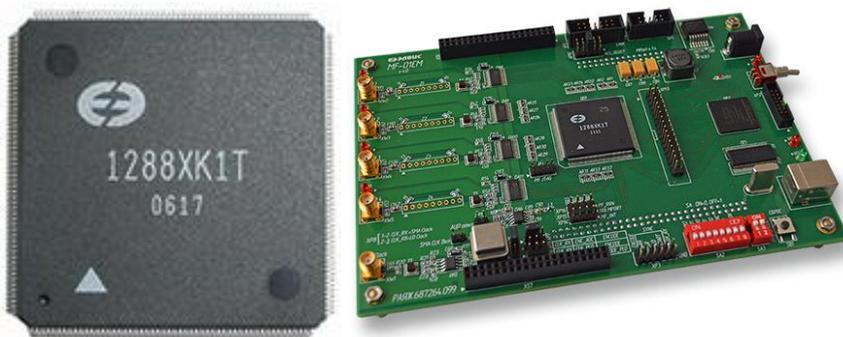
is a four-channel digital SDR-receiver Digital Down Converter (DDC), it is designed for implementation in the receiving paths of radio communication systems and radar.

Technical specifications of the chip are as follows:

- Four channels of a digital receiver with the ability to combine channels to implement a broadband path,
- Sampling rate of the input signal: over 100 MS/s per channel,
- Type of input signal: valid 16-bit digital signal, complex 16-bit digital signal, complex 8-bit digital signal,
- frequency conversion of the real and complex signal,
- SFDR of the local oscillator: 100 dB or better,
- The local oscillator accuracy: 0.025 Hz at a sampling frequency of 100 MHz,
- Phase accuracy of the local oscillator: 0.005 °,
- Two-stage digital decimator filter with fixed coefficients in each channel (first stage: 2 order CIC filter, second stage: 4, 5, or 6 order CIC filter),
- Total decimation coefficient: 1–16384,
- Two 64th-order programmable decimator filters with finite impulse response in each channel.

The performance of the SoC is sufficient for processing four narrowband channels or one wideband channel. Using the 1288XK1T SoC, it is possible to implement software-configurable phased and adaptive antenna arrays, including Smart Antenna and MIMO technologies.

JSC RDC “ELVEES” produces Multicor series processors, that are single-chip programmable multiprocessor SoC based on the IP core library of the MULTICOR platform and combine the qualities of microcontrollers and digital signal processors.



**Fig. 1.** 1288XK1T IC and evaluation board [9].

JSC “PKK Milander” produces: microcontrollers and microprocessors, debugging tools, memory, interface, radio frequency, power management, signal converter integrated circuits, as well as radiation-hardened devices which are offered in various packages.

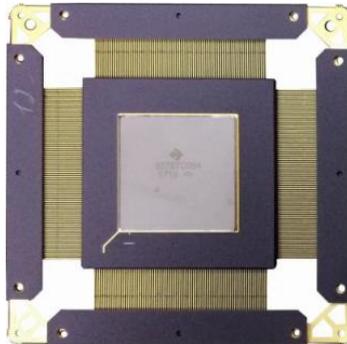
JSC “PKK Milander” [10] currently develops a frequency synthesizer with a fractional division coefficient and an integrated VCO with a fundamental frequency of up to 6 GHz at differential outputs. JSC “PKK Milander” produces frequency synthesizer microcircuits with a fractional division coefficient: 1508AC015, K1508AC015, K1508AC015K, 1508AC01N4, K1508AS01N4 with a fundamental frequency of up to 12 GHz. These circuits can be implemented as local signal generators in a phase-locked loop system, which in turn can be used in base stations for mobile radio, wireless local networks, or in space radar systems.



**Fig. 2.** 1508AC015 IC and evaluation board [10].

Joint Stock Company “VZPP-S” [11] produces Field Programmable Gate Arrays circuits that are functionally compatible with Altera products. For example, FPGA 5578TS094 TU - AENV.431260.423TU are designed to replace EP3C25 Altera microcircuits. The main functional parameters of such circuits are as follows [12]:

- System gates capacity - 1 200 000,
- Equivalent logic gates count - 24 624,
- Internal memory - 594 KB,
- 18x18 multipliers count - 66,
- Programmable outputs count - 195.



**Fig. 3.** 5578TC094 FPGA [12].

JSC “NPF Mikran produces wireless broadband access equipment based on the IEEE 802.16-2004 WirelessMAN (WiMAX) recommendation in the frequency range 5.650-6.425 GHz, having the following specifications [13]:

- efficient use of the spectrum (up to 37 Mbps in the 10 MHz band),
- lack of collisions in the band,
- robust work in the conditions of multipath reception,
- guaranteed quality of service at the level of service flows,
- multiservice (voice, video, data),
- organization of networks with the topology “point - many points” and “point - point”.

NPF Mikran JSC also manufactures equipment for digital radio-relay stations (DRRS) in the range 4 ... 23 GHz with a data speed of up to 3.6 Gbit / s per interval and antenna devices for them in the range 4 ... 18 GHz. Such equipment, with appropriate adaptation, can be used in Relay Node technology. The company is also currently adapting digital phased array technology for use in 5G base stations [14].

On December 21, 2017, Roselektronika Holding began production of gallium nitride (GaN) power transistors for 5G communication networks. Product is developed by JSC “Research Institute of Electronic Technology” (as part of the holding is part of the Sozvezdie Concern). Microwave/GaN transistors in communication networks will increase the amount of transmitted data due to a larger frequency range.

The output power of such devices is from 5 to 50 W, the power gain is from 9 to 13 dB, the drain efficiency is not less than 45% at the test frequencies of 4 GHz and 2.9 GHz. Transistors are completely interchangeable with imported analogs, which eliminates the need for additional matching settings as part of the equipment [15].

According to the results of testing the Elbrus 401-RS workstation based on the Elbrus 4C quad-core processor to implement a safe computing mode in the field of relay protection of automation of electrical substations, it was decided to develop an industrial computer based on the Elbrus 4C processor. According to the requirements of IEC 61850 (IEC 61850) for relay protection devices of automation, the data frequency of a transformer is 4 MHz [16]. The Elbrus 4C processor has a clock frequency of 800 MHz and supports operation at data transfer rates up to 1000 Mbps.



**Fig. 4.** «Elbrus 401-PC» workstation [17].

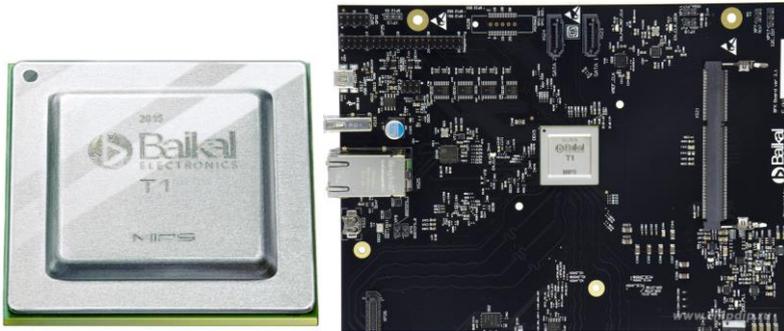
The MCST and INEUM companies are currently develop the Elbrus 16SV microprocessor, which is scheduled for release in 2021 [18]. Table. 1 shows a comparison between Elbrus and Intel processors.

**Table 1.** Performance comparison between Elbrus and Intel processors [18].

Parameter	Intel Xeon E7-4850 v4	Intel Xeon Platinum 8153	Elbrus-16SV
Architecture	Broadwell	Skylake	“Elbrus” v6
Clock frequency (turbo), GHz	2,8	2,0 (2,8)	2,0
Peak performance, sd/dp (turbo), GFLOPS	1075/538	1200/600 (1600/800)	1500/750
Core number	16	16(28)	16
Cache size, MB	40	38	> 32
Memory data rate, GB/s	85	119	> 100
Technology node, nm	14	14	16
Power consumption, W	115	125	100
Performance/Power, GFLOPS/W	4,7	4,8 (6,4)	7,5
Production year	2017	2017	2021

OJSC Baikal Electronics produces a system on a chip based on the MIPS Warrior P-class P5600, Baikal-T1 architecture [19]. The device has the following specifications:

- 2 cores P5600 MIPS 32 r5, operating frequency 1.2 GHz,
- L2 cache capacity - 1 MB,
- DDR3-1600 memory controller,
- Power consumption less than 5 V,
- Technological process 28 nm,
- Integrated Interfaces:
  - 1 10 Gb Ethernet,
  - 2 1 Gb Ethernet,
  - PCIe Gen.3 controller
  - 2 SATA 3.0,
  - USB 2.0



**Fig. 5.** Baikal-T1 SoC and Baikal-T1 processor-based computer [19].

In addition, many research teams are currently involved in the development of equipment and technical solutions for 5G networks. In particular, design teams of MIET university develop transceiver equipment for organizing networking according to the requirements of the fifth generation of mobile communications. The development is based of National Instruments rapid prototyping and debugging equipment using USRP-2943R units operating in the range up to 6 GHz [20].

In the course of the work, algorithms and software of experimental sample of hardware-software complex of transceiver equipment were developed for organizing network interaction according to 5G requirements. This includes:

- algorithm for determining the location of radio facilities of network subscribers,
- algorithm for the medium analysis that determines channel occupancy, noise power level, subscriber location and channel status information,
- algorithm for implementing a multiple MIMO signal processing system, including a program for determining the propagation conditions of signals from different beams and compensating for intermodulation distortion,
- algorithm for the implementation of packet communication protocols,
- algorithm for estimating and implementing signal predistortion to compensate for the peak factor,
- algorithm of the OFDM modulator with universal filtering (UF-OFDM) and cyclic prefix (CP-OFDM),
- algorithm for communications facility control in a software-configurable network (SDN) mode.

The presented review of the products of Russian enterprises allows us to draw conclusions about the possibility of producing Russian telecommunications equipment for 5G networks.

## 5 Conclusions

The Government of Russian Federation decided to form a unified register of Russian radio-electronic products by January 1, 2020, having developed a list of products originating from foreign countries and a procedure for determining the status of telecom equipment of domestic production. The corresponding Cabinet resolution of July 10, 2019 is available on the official Internet portal of legal information.

According to the document, within a two-month period, the Ministry of Industry and Trade was instructed to develop a procedure for assigning and confirming the status of telecommunication equipment of Russian origin and its inclusion in the register, as well as the procedure for conducting on-site inspections for the examination of equipment in the applicant's territory. In addition, from September 1, 2019, the Ministry is obliged to ensure the formation and maintenance of a register in the state industry information system, and until January 1, 2020 to approve the requirements for the level of localization of telecommunication equipment production and the methodology for determining the Russian origin of such products.

Work on the implementation of the 5G network in Russia is carried out by many research organizations and teams in conjunction with industrial enterprises. Base stations of the 5G network can be created on the basis of existing samples of telecommunication equipment of Russian production based on Russian components using Russian software. For mass production, adaptation to existing mobile communication networks and unification of Russian-made telecommunication equipment in order to ensure the commercial operation of 5G networks, it is urgent to formulate uniform technical requirements for the base station software and hardware platform in accordance with IMT-2020 documents.

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