The Role of Radio Frequency Spectrum in the Development of the Economy and the Formation of the Information Society

Volodina Elena[1][a], Kukharenko Elena[1][b] and Sukhodolskaya Tatiana[2][c]
Moscow Technical University of Communication and Informatics, Moscow, Russia
[2]Radio research & development institute, Moscow, Russia
evolodina@list.ru, e.g.kukharenko@mtuci.ru, tsukhadolskaya@gmail.com

Keywords: digitalization of society, ICT, spectrum, mobile communications, 5G.

Abstract: The article gives the definition of the concept of "information society" given by well-known scientists. It reflects the driving role of information and communication technologies in the development of the information society. The article gives the list and place of specific production resources in the ICT industry, including spectrum. The interrelation of the development of ICT and economics from the point of view of A. Gipp and L.E. Varakin is revealed. The data confirming the considered pattern are presented using the example of up-to-date information on the development of modern technologies and macroeconomic indicators of various countries. Various fields of activity using spectrum as production resource are observed. The features of spectrum as a natural phenomenon and a production factor, its place and role in the manufacturing infrastructure and society are noted on the example of further development of mobile communications, in particular 5G networks. The requirements for a radio frequency resource for the development of promising networks are given. The problems associated with the implementation of 5G networks as a necessary infrastructure for the digital society and the economy transformation are identified. These problems require the development of scientifically based measures and their immediate solution.

1 INTRODUCTION

In the context of the rapid development of the infocommunication industry, digital technologies significantly affect the life of each person, and they affect the economy even more seriously (Salutina, Klesareva etc., 2021; Kukharenko, Korkunov etc., 2019; Gumerov, Salutina etc., 2022).

The changes are so rapid that companies and the entire economy of the country need a widespread and rapid transition to a new digital paradigm to ensure stable rates of development and maintain competitiveness (Devyatkin, Volodina etc., 2020).

Since the end of the 20th century, the world has begun to implement a qualitatively new generation of digital technologies. This stage is commonly called the age of informatization, which is characterized by a global transition to an information society based on existing and new digital networks that are used for various purposes (communications, data transmission, computing, etc.) (Salutina, Platunina etc., 2021).

The definition of a term ‘information society’ that has been given by various scientists can be found in various sources. Let us consider some of them. According to D. Bell, information society should be considered in several aspects: as a society where codified knowledge is of primary importance; as a society of services; as a society where the main role in decision-making belongs to intellectual technologies (Bell, 2004).

When forecasting the development of science and technology in Russia for the period up to 2025 academician A.I. Rakitov describes the information society as a society where all means of information and telecommunication technologies are aimed at making information accessible and actively implemented in production and life (Rakitov, 1998).

The basis of the information society is information and communication technologies (ICT),

[a] https://orcid.org/0000-0002-0310-8258
[b] https://orcid.org/0000-0002-6309-6498
[c] https://orcid.org/0009-0002-1812-9630

which affect all social institutions, including education, economics, healthcare, government and other infrastructures. (Kukharenko, Yankevskiy, 2023; Kukharenko, Alyushina, 2021).

ICT is an extensional term for information technology (IT) that stresses the role of unified communications and the integration of telecommunications (telephone lines and wireless signals) and computers, as well as necessary software, storage and audiovisual, that enable users to access, store, transmit, understand and manipulate information (Hilbert, 2023; Ozdamli, Ozdal, 2015).

One of the specific features of the process of producing information and communication services is that in contrast to other types of economic activity the unique resources (information, numbering resource and radio frequency resource (radio frequency spectrum)) are used in addition to the classical resources of economic theory (labor, fixed and working capital, etc.). It is interesting that the use of information resources leads to an increase in their volume, and the use/distribution of numbering resource and radio frequency resource leads to their deficit (Volodina, 2018).

In the Russian Federation there is a particular lack of radio frequency spectrum that is an indispensable production factor necessary for all sectors of economy where wireless communications are used. This article reflects the results of work aimed to give an economic assessment of spectrum as a resource needed to produce the most popular and promising mobile communications services, which are the basis for the digitalization of the economy and society. The results of the study are necessary to determine a number of specific scientific and applied tasks to improve the spectrum usage management in terms of its effective distribution. Such tasks should include the development of organizational and technical measures to release the radio frequency spectrum, modernization of the auction process in the Russian Federation, as well as problems of stimulating access to radio frequencies as a valuable resource for innovative economy and information society development.

2 THE RELATIONSHIP BETWEEN THE DEVELOPMENT OF ICT`S AND THE ECONOMY

The relationship between the development of information and communication technologies (ICT) and the economy of any country is determined by their classification as public infrastructure. Moreover, the activities in other infrastructure sectors of the economy are impossible without ICT, including radio technologies. Infocommunication technologies are necessary for both the production and consumption of goods and services, covering and servicing all market participants, expanding its scale, actively influencing the economy, management, business development and improving people's well-being.

Researchers have determined a direct relationship between the rates of economic development, the standard of living of the population and the rates of ICTs development. As early as the mid-1970s, some scientists spoke about the existence of a close relationship between the level of development of telecommunications and macroeconomic indicators. Thus based on a study of statistical data from various countries A. Jipp established a correlation between telephone density and gross domestic product per capita (Jipp, 1963).

In Russia, L.E. Varakin studied the patterns of development of telecommunications in relation to macroeconomics (Varakin, 2006). He made his methodological and theoretical contribution to this scientific field by proving the information-economic pattern. The scientist proved that the volume of information transmitted by means of communication is proportional to the country's GDP (Varakin, 2001)

The pattern, identified by scientists, can also be observed in terms of the most promising radio technologies providing broadband access, namely: the higher is the level of broadband access penetration, the greater the GDP in the country is (Butenko, Veerpalu, etc., 2009; Volodina, 2018). Figure 1 shows the grouping of countries with different levels of economic development (GDP) depending on broadband access penetration.

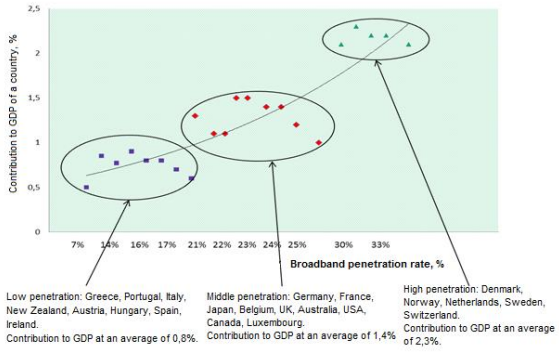

Figure 1: Broadband penetration rate by country group with different levels of economic development.

According to scientists (Jipp, 1963; Varakin, 2006), the growth of ICT should exceed the growth rate of the economy as a whole in order to perform the digitalization of other spheres of activity successfully. An important trend is an increase of an indirect effect, i.e. the effect achieved in other spheres, from the introduction of digital technologies in various industrial and non-industrial spheres of activity.

According to the results of research by Russian specialists by 2030, more than half of GDP growth will be due to the digitalization industry and, as a result, increased efficiency in other sectors of the economy. Figure 2 shows that over the period from 2017 to 2030, the contribution of digital ICT to GDP will be about 4%, and due to the indirect effect of digitalization of other industries — about 30%.

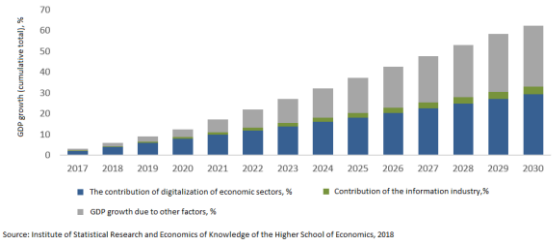

Figure 2: The contribution of digitalization to economic growth (cumulative total from 2017 to 2030, %).

3 THE CONCEPT OF RADIO FREQUENCY SPECTRUM AND ITS PLACE IN PUBLIC INFRASTRUCTURE

The meaning of the term "radio frequency spectrum" is related to the existence of one of the physical fields - electromagnetic, which does not exist constantly, but appears either at the moment of manifestation of natural phenomena such as solar radiation, flashes, thunderbolts/lightning etc., or as a result of the operation of technical means. (Bykhovsky, 2006)

In order to provide communication services and to ensure the operation of private networks, a man creates electromagnetic fields artificially with the help of radio equipment, for example radio electronic means in telecommunications; high-frequency devices in industry, medicine and other areas of human activity (Volodina, 2017).

Industrial use of radio frequencies began in the 1920s. After the invention of the telegraph, telephone and teletype, radio relay lines began to be used in various spheres of activities to transmit information. Due to the invention of radio, technological processes were transferred from wired to wireless communications.

It is interesting that only governmental and private networks used radio communication until a few decades ago. With the introduction of radiotelephone communication new prospects for the use of the spectrum appeared. It opened the way for the provision of cellular mobile communication services as well as the operation of new generations of satellite communication systems.

Technological progress constantly defines new possibilities for the use of radio frequencies (Volodina, 2018). At the current stage of ICTs development, frequency resource, along with other production resources, is necessary:

- to produce information and communication services;
- to operate private networks in various sectors of the economy;
- to ensure national security and defence capability of the country;
- to operate astronomical and meteorological instruments, electronic household appliances, etc.

The spectrum is widely used in ICT for the provision of mobile and satellite services, broadcasting, access to Internet, etc. In industry, radio frequencies are used for the operation of private networks that support production processes. As research has shown wireless communication is especially important for enterprises in the mining and manufacturing industries, primarily in the gas, oil and coal mining industry, non-ferrous metallurgy, energy, etc. As a rule, these enterprises have their own spectrum license for the operation of their private networks. They are also making a one-time and annual payment for frequencies' use to the state budget.

Organizations and institutions such as banks, transport, travel, security and utilities companies, hotels, etc. also use spectrum to operate their private networks and to provide state, financial and household services. If enterprises and organizations do not have individual permits to use frequencies, they use the services of companies providing corporate wireless communication services.

The frequency spectrum plays an important role in ensuring national security and defence capability of the country. It helps to solve special (military and governmental) tasks, ensure air traffic and in emergencies. It should be noted that a significant part of the radio frequency resource is assigned specifically for government services.

Today, in the context of digital transformation, the role of radio frequency resource used in the production process of enterprises is constantly increasing. This is due to the fact that the demand for wireless communication services is increasing, which requires more radio technical means and radio.

4 THE PLACE OF SPECTRUM IN THE INDUSTRY AND SOCIAL INFRASTRUCTURE ON THE EXAMPLE OF MOBILE COMMUNICATIONS

The most important indicator of the economic activity of the ICT is revenue from services. According to the Ministry of Communications of the Russian Federation, revenues from communication services, including revenues from spectrum usage management, in 2023 amounted 2140,93 billion roubles.

Industry statistics shows that the share of revenues from the provision of new mobile communications, radio, broadcasting, television and satellite services, taking into account mobile broadband access to the Internet, currently accounts more than 70% of total communications revenues compared to 20% in 2001.

Further development of information and transport infrastructure is impossible without wireless access networks, and, consequently, without the use of the radio frequency spectrum, which is an indispensable production resource. Currently, almost all relevant innovative services are connected to the Internet. At present, a basic Internet network has been created in Russia based on fiber-optic communication lines, but the means of accessing this network, especially in rural areas and in remote regions of Russian history, require development, and this is possible only using radio technologies. Today, this condition has no alternative, even in the long term.

Most clearly, the prospects and role of spectrum use can be observed on the example of the introduction and operation of 5th generation mobile networks (5G). According to experts, the introduction of mobile networks of mobile communication technologies 5G and 6G, artificial intelligence (AI), the Internet of Things (IoT) and big data will ensure the economic growth of states in the future up to 2030. All these technologies serve as the basis for the digital transformation of industrial production (Devyatkin, Ivankovich, 2021).

The concept of 5G is much broader than the definition of a traditional wireless network. Today, 5G is a universal platform, the technological basis for human life, the socio-economic activity of the entire society. Technologies are no longer just a technological innovation and competitive advantage, but an urgent need, a basic resource for companies in most sectors of the economy.

Thus, fifth-generation technologies and services are becoming the infrastructure and technological basis for the digital transformation of the economy and society, new business models and industry development scenarios.

According to their functional purpose and basic capabilities, 5G services can be divided into three groups:

enhanced Mobile Broadband (eMBB) – high data transfer rate (100 times higher than in 4G networks). It is intended for private users: access to interactive services, multimedia.

Ultra-Reliable Low Latency Communication (URLLC) – high requirements for speed, bandwidth, and waiting for the service to be ready (8 times less waiting time than in 4G networks). Designed for corporate organizations and government agencies.

Massive Machine-Type Communications (mMTC) – connection of a large number of devices transmitting small data packets. Supports applications using Internet of Things (IoT) sensors.

All three basic services in various combinations can be used to organize systems and applications in various industry sectors and will replace or complement the most of wired and wireless technologies in the future.

According to a 2021 study, the impact of 5G on the economy of key markets (manufacturing, agriculture, transport, retail, etc.) from 2025 to 2030 will increase almost 3 times and the predicted effect by the end of this period will be more than 500 billion USD (Figure 3).

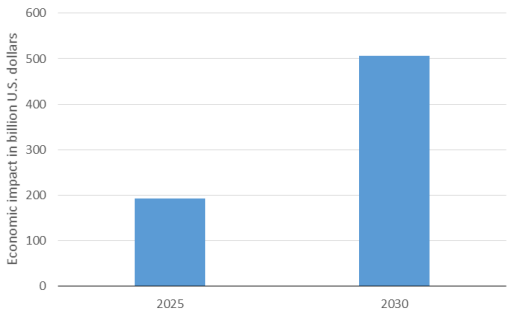

Figure 3: Estimate of digitalization economic impact using 5G in key vertical (production, agriculture, transport, retail) in 2025 and 2030.

5G networks are the main infrastructure for the development of IoT, which represents huge potential for business development in a variety of fields (Figure 4).

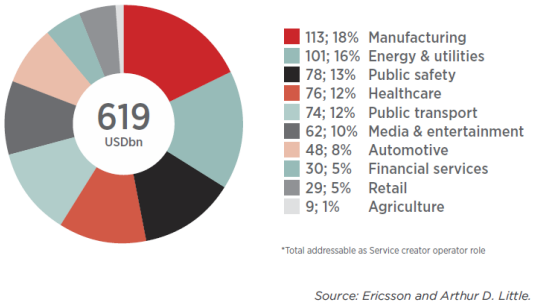

Figure 4: 5G-IoT Business Potential.

Forecasts for the Russian market also indicate a threefold increase in the economic effect from the use of 5G from 2025 to 2030 (Figure 5).

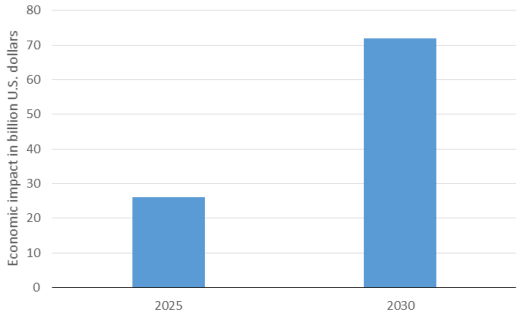

Figure 5: Estimated impact of digitalization using 5G on key sectors of the real economy in Russia from 2025 to 2030.

In accordance with the Concept that is presented on the website of the Ministry of digital development, the largest part of revenues from the introduction of 5G services will be received in industry and housing, and in general, the income of 5G/IMT-2020 market participants will amount to at least 37 billion US dollars, See Figure 6.

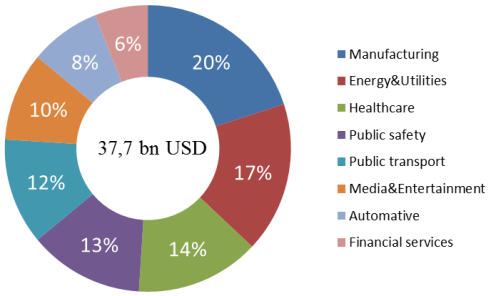

Figure 6: Distribution of revenues of 5G/IMT-2020 market participants from the introduction of services in various industries of the Russian Federation in 2026.

According to the results of the RAEC's research, the share of indirect effect from the development of mobile communication technologies will constantly grow and by 2030 may amount to more than 5% of the GDP of the Russian Federation (Figure 7).

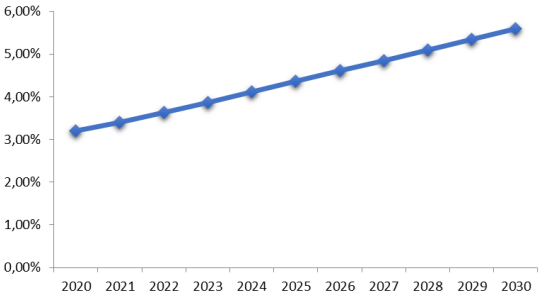

Figure 7: Forecast of the indirect effect from the development of mobile communication technologies until 2030 as a share of GDP.

The assessment of such tangible results of the functioning of wireless communication technologies, their role in the business of the industry and macroeconomic indicators shows that the technological basis for the further development of cellular mobile communications is an indispensable resource - the radio frequency spectrum. Therefore, the spectrum should be accessible both from a physical and from an economic point of view (Volodina, Kukharenko etc, 2021).

To provide 5G/IMT-2020 services, it is necessary to meet certain technical requirements that are optimally implemented in different frequency bands. The Technical Specifications of the 3GPP project considers the following frequency bands for 5G/

IMT-2020 networks: 450-6000 MHz and 24.25 – 52.6 GHz. GSMA documents-consider three bands: below 1 GHz; 1-6 GHz; over 6 GHz.

As practice shows, in some countries, in particular, Korea and US, operators abandon the millimeter range due to high costs of the deployment of base stations. The lack of demand for one of the allocated sub-bands indicates that there is less and less spectrum for 5G. According to GSA, 150 operators have launched their networks in the 3,5GHz band, 50 in sub-gigahertz and slightly more than 50 operators in the 1 to 3 GHz band.

In the Russian Federation, for the successful implementation of the digital economy by building a multi-band 5G/IMT-2020 network, it is necessary to allocate radio frequency bands in the following bands [Concept.]:

- 694-790 MHz: will allow the development of 5G/IMT-2020 services in sparsely populated areas, as well as ensure the implementation of IoT/M2M services;
- 2.3-2.4 GHz: will increase the data transfer rate and capacity of 5G/IMT networks-2020;
- 4.4-4.99 GHz: will allow the organization of high-speed channels in areas with high density and support for the main set of 5G/IMT-2020 services. The use of this band will allow operators to solve the same tasks as the 3.4-3.8 GHz band, taking into account that the use of the 3.4-3.8 GHz band in the near future in the Russian Federation will be difficult;
- 24.25-29.5 GHz: will allow the organization of ultra-high-speed communication channels at short distances from the base station, coverage in hot spots, and provision of all types of 5G /IMT services-2020.

As already mentioned in the article, there is a shortage of "clean" spectrum in the Russian Federation, i.e. spectrum that is free from other radio equipment and is ready for new technologies. Allocation of the necessary radio frequency resource to mobile operators, as well as determination of the conditions of its use, is carried out by the State Commission on Radio Frequencies in accordance with the established procedure. The procedure for obtaining permission to use radio frequencies is complex and multi-step. A number of bands require release from radio equipment that currently operates in the frequency bands intended for 5G/IMT-2020 networks. This leads to large-scale work on spectrum redeployment, modernization of equipment and conduction of organizational and technical measures.

In addition, due to the limited amount of radio frequency spectrum, the main way to distribute it is to hold an auction. According to the national regulation, the winner receives a license for the provision of communication services using the radio frequency spectrum. It should be noted that there were four auctions announced in the Russian Federation but only two of them were held.

In the current situation, there is a need to stimulate the innovative and investment activity of cellular mobile operators on the part of the state in terms of the availability of a radio frequency resource during auctions, as well as fees for its use during the license period (Volodina, Sukhodolskaya, 2024; Volodina, 2019).

The considered problems indicate the need to improve the parameters and procedures that should be aimed at effective spectrum management, which is relevant in the aspect of progressive development of mobile and satellite communications, digitalization of the economy and society.

5 CONCLUSIONS

Analysis of theoretical, scientific and statistical sources allowed the authors to identify the features, trends and role of the use of radio frequency resource in the formation of the digital economy, which are as follows:

The patterns of interrelationship between the development of ICT, including radio technologies, and the economies of countries have been identified, which is substantiated by a number of scientists and industry statistics.

The understanding of the indispensability of radio frequency resource in the production process of mobile operators, whose networks are an essential element of the infrastructure for the digital transformation of the economy and society, is revealed.

Statistics is provided confirming the enormous economic effect of the introduction of 5G networks in all key sectors of the digital society.

A number of problems regarding the use of radiofrequency spectrum intended for the development of 5G on both the global and Russian markets, and ways to solve them have been identified.

Thus, the successful implementation of the digital transformation of society depends on the provision of radio frequency resource, and the primary tasks of digitalization move into the area of effective management of the use of radio frequencies.

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