

# Spectrum Switchover for Commercial use and “Spectrum Procurement” Contest

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**Abstract:** Motivated by the need to implement wireless broadband mobile communications (Long Term Evolution (LTE)) in the “Digital Dividend” band (790-862 MHz) in Russia and to relocate government users of spectrum, especially the Aeronautical Radio Navigation Service (ARNS), this article focuses on the funding of organizational and technical measures to relocate government users from the spectrum and to transfer the spectrum to commercial users. To this end, various spectrum reallocation procedures used worldwide are analyzed. The results show that the existing territorial division of communication services limits the development of new communication technologies in neighboring countries, indicating the need for international harmonization with regard to spectrum management measures. The LTE contest (2012) in Russia could be considered as a hybrid procurement and spectrum contest rather than a standard spectrum contest. The ARNS migration mechanism proposed by the Russian regulator is based on “extensive” spectrum usage and is similar to the logic of the U.S. Commercial Spectrum Enhancement Act.

**Keywords:** Spectrum Relocation Fund, LTE Deployment, ARNS Migration, Spectrum Contest, Procurement Contest

## Introduction

Subject to the decision of the World Radio Communication Conference (WRC) of 2007, radiofrequencies (RFs) from 790 to 862 MHz (the “Digital Dividend” range [1]) have been allocated to Mobile Communication Services (MCS) in 40 countries of Radio Region 1 of the International Telecommunications Union (ITU) [2] since January 1, 2009. Beginning June 17, 2015, the MCS will be allocated to the Digital Dividend range for all countries in Region 1. The WRC of 2012 (WRC-12) agreed on new regulation procedures for joint spectrum usage [3] and coordination criteria for International Mobile Telecommunications (IMT) and Aeronautical Radio Navigation Services (ARNS) (ITU, 2012b). Accordingly, RFs from 694 to 790 MHz (the “Digital Dividend-2” range) were allocated to IMT. Similar to the Digital Dividend band, compulsory IMT-ARNS [4] coordination was approved for Digital Dividend-2.

Digital Dividend has been primarily allocated to radio navigation services in 19 Central and Eastern European countries, Western, Central and Eastern Asian countries (i.e., Armenia, Azerbaijan, Belarus, Bulgaria, the Russian Federation, Georgia, Hungary, Kazakhstan, Moldova, Mongolia, Uzbekistan, Poland, Kyrgyzstan, Slovakia, the Czech Republic, Romania, Tajikistan,

Turkmenistan and Ukraine) [4]. These countries belong to the Regional Commonwealth in the field of Communications (RCC) or the European Conference of Postal and Telecommunications Administration (CEPT). This membership affects their ability to develop new Wireless Communication (WC) technologies.

Compared with that in higher spectrum ranges, signal propagation in the Digital Dividend and Digital Dividend-2 ranges permits the development of IMT in remote and rural territories at lower cost because fewer base stations are required to provide communication services [6]. These advantages explain the considerable attention paid to spectrum bands below 1 GHz. However, the development of next-generation WC technology is a top priority for any country.

In Russia, economic policy and national budgetary considerations focus on the development of the high-technology sector. In many national economies, finding additional frequency spectra is necessary to develop modern communication technology. Changes in technology use are also common. Similar to other nations, Russia suffers from a limited frequency spectrum largely because of the high spectrum consumption by government users. In 2012, the Russian Federation proposed a competitive, national-level spectrum allocation procedure for the right to

deploy Long Term Evolution (LTE). The spectrum was allocated in the form of a contest (hereinafter referred to as “LTE contest”). This article discusses the funding of organizational and technical measures to relocate government spectrum users (especially ARNS) and the reallocating of the spectrum to commercial users, specifically the current LTE spectrum allocation in Russia.

## Background Literature

### *Market Approach to Manage Spectrum Freeing*

In their study of the interactions among current spectrum users (incumbents), new spectrum users (entrants) and the Federal Communications Commission (FCC) during spectrum reallocation, Crampton *et al.* (1998) noted that proper negotiations between the incumbents and entrants may contribute to improved efficiency. However, their analysis did not consider compensation to government users of the spectrum. The terms and conditions of the contest for the 4G spectrum in Russia provided for compensation to former spectrum users although this requirement was specific for license awardees and was only specified in the contest documents.

De Vany (1998) focused on optimal market mechanisms for freeing the spectrum. De Vany proposed the “relocation-compensation game” mechanism [7] and considered the need to develop a market for spectrum property rights after primary auctions [8]. Arguments on the effective allocation of a limited natural resource (spectrum) in the case of its insufficient or ineffective usage were used to support this approach. Since the publication of De Vany’s paper, technological developments [9] have been made, which allow us to make a major step toward solving the issue of underutilization or temporary non-utilization of the spectrum by current license holders. However, the spectrum license is not transferred and the application of the De Vany’s approach to the relocation of federal spectrum users can hardly be achieved.

### *Spectrum Relocation Funds*

In 1995, the U.S. National Telecommunications and Information Administration (NTIA) reallocated the 220-MHz spectrum from federal government users to the private sector in response to a directive from the U.S. Congress (USC, 2011). The cost of this relocation has been estimated to range from \$477 million to \$592million (NTIA, 2006). In 1998, the U.S. Congress approved the Strom Thurmond Act to reimburse expenses to the relocated federal agencies (USH, 1998) with provisions for direct compensation to federal agencies from non-federal license holders. In 2004, the U.S. House passed the Commercial Spectrum Enhancement Act (CSEA) and the Spectrum Relocation

Fund (SRF) was established to reimburse expenses of federal agencies because of the reallocation of specific RFs to the non-federal sector (USH, 2004).

In France, starting in 2007, the French SRF (Fonds de Réaménagement du Spectre (RFS)) has assigned 75 million euro to support spectrum freeing and develop new technological solutions: 150 MHz to IMT-2000, 25 MHz to GSM-1800 and 83 MHz to WiFi (Guitot, 2010). Since 2003, the RFS has been used to fund spectrum freeing for the development of digital television in France. The RFS receives money from the government and private sources although similar funds can be obtained by private sponsorship only [10].

### *Effects of Spectrum Reallocation on Industry Competition*

To assess the effects of spectrum allocation methods on telecommunication networks, Lundborgn *et al.* (2012) compared the costs for network access and for the RF spectrum. They found sufficient economic diversity [11] between the spectra below and above 1 GHz due to propagation characteristics. Although the diversified level of rates for different spectrum bands at the spectrum auctions has no effect on the competition at the MCS market level, administrative (non-market) spectrum reallocation may cause distortion in the competition.

Lundborgn *et al.* (2012) recommended that propagation characteristics of the spectrum bands be considered when the spectrum is reallocated. For example, in the early 1990 s in the EU, the 2G spectrum was allocated to one to two operators at 900 MHz. Entrants could later purchase the spectrum, mostly on the 1800-MHz band. However, the existing equipment of the operators (e.g., base station grids) cannot be used if the spectrum range changes because of technological limitations (Lundborgn *et al.*, 2012).

### *Refarming of the Spectrum in the EU*

The main reason for refarming [12] is the need to more effectively utilize limited resources (i.e., spectrum). The main refarming technology in the EU is 3G. To minimize the effect of institutional restrictions on spectrum refarming and to ensure the most efficient use of the spectrum, associating refarming with the current licensing process is not advisable (e.g., termination, renewal of existing and issuance/introduction of new licenses) (Cabello, 2009). Cabello (2009) provided three main objectives for spectrum refarming at 900/1800 MHz: (1) to increase the possibility of using new technology (3G/4G) with current licenses (2G), (2) to lift technological restrictions by the regulator and allow license holders to select the technology to be used and (3) to establish equal competition (e.g., provide access to operators

without 2G licenses at 900 MHz to a more profitable spectrum band). In this context, profitability means cost savings on the development of new technology.

### *Relocation of ARNS to the MCS Spectrum*

Subject to international recommendations, ARNS will have protection until 2015. Based on the GSM Association order, the company Analysys Mason analyzed the potential cost of relocating ARNS from the Digital Dividend band to another spectrum range in Russia after 2015 [13]. Figure 1 shows the analyzed MCS deployment scenarios.

## **Harmonization of WC Deployment and Relocation of Government Spectrum Users**

### *Level of MCS Development in Different Countries*

Industry reports show a relatively high level of MCS development in Russia and in the Commonwealth of Independent States (CIS), with relative figures for MCS subscribers in the CIS having dominated the world since 2009 (Table 1). However, the level of penetration of *broadband* MCS in the CIS is lower than the average European figures, although it is comparable with the American figures (Table 2). Nevertheless, the continuous growth of WC technology has resulted in the lack of spectrum.

### *SRF for Freeing the Spectrum from Federal Government Users*

In 2003 in the U.S., the NTIA and FCC began planning the reallocation of the 1710-1755-MHz band to non-government users [14]. As a centralized mechanism to reimburse expenses associated with the reallocation of the federal radio-communication systems, the SRF was created at the end of 2004, funded by income from the auctions of rights for the commercial usage of the 1710-1755-MHz spectrum band (USH, 2004).

The Advanced Wireless Services (AWS)-1 has been allocated to the 1710-1755-MHz and 2110-2155-MHz bands. From August to September 2006, the FCC held auctions of licenses for the AWS-1 in the 1710-1755-MHz band, which raised \$13.7 billion (NTIA, 2006). Table 3 lists the licenses that were auctioned. The income from the auction of the AWS-1 was used to reimburse the expenses in relocating existing government users in the 1710-1755-MHz band (USH, 2004). A reserve price of 110% of the expected cost of freeing the 1710-1755-MHz band was set. In other words, the sale of the spectrum was prohibited if the net sales were less than 110% of the planned cost of relocating the federal system (USH, 2004; FCC, 2006).

The 1710-1755-MHz band was used by 12 federal agencies. The NTIA assigned 1,990 federal frequencies in this band. The relocated federal communication systems were as follows: (1) fixed microwave systems for voice and data transmissions, which cover wide spheres of activity; (2) special systems (e.g., law-enforcement surveillance systems); and (3) mobile aviation systems, which support national safety and research/scientific activities. At the end of 2005, the initial cost of freeing the 1710-1755-MHz spectrum band was estimated at \$936 million. After some federal agencies updated their relocation plans, the estimated cost increased to \$1.009 billion in 2007 (OMB, 2007).

The SRF became available to the recipients only when federal users were moved from the spectrum reallocated to non-federal users through a tender or auction process (USH, 2004). A competitive tender for licensing new spectrum users could not be obtained if the spectrum was used for non-licensed, joint, non-profit, or national safety purposes.

### *Spectrum Refarming Regulations in the EU*

According to the EU regulations regarding spectrum refarming (EC, 2009), the market situation should be assessed before and after refarming. An initial spectrum allocation below 1 GHz (for GSM technology) offers a more competitive position for spectrum users who own larger-spectrum regions in the 900-MHz range (after spectrum refarming for LTE). These legislation limitations are intended to prevent the dominance of local market leaders after spectrum refarming (Lundborgn *et al.*, 2012). Most EU countries have one or two dominant operators in the MCS market. In Russia, the market is more competitive; four major nationwide players exist, one of which owns a substantial stake in the fixed-line broadband market. Several small players also exist in the sub-federal markets.

### *Relocation of Government Systems for LTE Deployment in Russia*

The Digital Dividend range (790-862 MHz) offers excellent propagation characteristics for developing broadband mobile services, which requires lower capital expenses for infrastructure construction (fewer base stations) when developing rural areas compared to higher-frequency ranges. Another option for LTE is to use a combination of the spectral bands at 2100, 2600 and 900 MHz after spectrum refarming (AM, 2010; Glushko *et al.*, 2010). However, according to the State Commission of Radio Frequencies of the Russian Federation (GKRCH), spectrum refarming at 900 MHz is not a priority for LTE development in Russia; this band is currently allocated to ARNS and spectrum conversion [15] would be required (GKRCH, 2011).

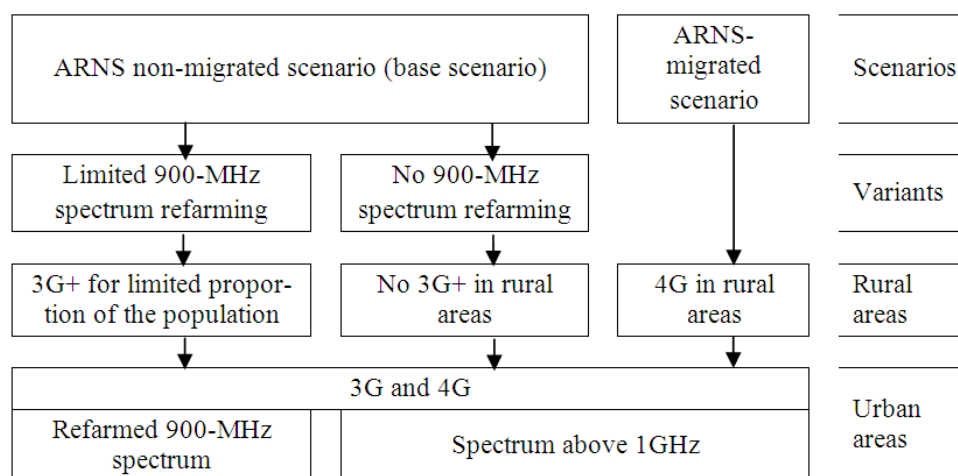


Fig. 1. Russia's 3G and 4G deployment scenario; Source: Based on (AM, 2010)

Table 1. Mobile service indicators for developed and developing countries and the world (penetration rates)

Countries	Per 100 inhabitants								
	2005	2006	2007	2008	2009	2010	2011	2012 <sup>a</sup>	2013 <sup>a</sup>
<b>Mobile-cellular subscriptions</b>									
Developed	82.1	92.9	102.0	108.3	112.5	115.0	119.0	123.6	128.2
Developing	22.9	30.1	39.1	49.1	58.3	69.0	78.3	84.3	89.4
World	33.9	41.7	50.6	59.8	68.1	77.2	85.5	91.2	96.2
Africa	12.4	17.8	23.5	32.4	38.4	45.7	53.6	59.8	63.5
Arab states	26.8	38.8	52.6	63.0	76.2	87.7	96.4	101.6	105.1
Asia and pacific	22.6	28.8	37.1	46.6	56.3	67.7	77.3	83.1	88.7
CIS	59.7	81.8	96.1	112.2	127.5	135.1	147.0	158.9	169.8
Europe	91.7	101.2	111.7	117.2	117.0	117.6	120.1	123.3	126.5
The Americas	52.1	62.0	72.1	81.5	88.0	95.0	101.4	105.3	109.4

<sup>a</sup>Estimate. Rounded values. N/A: Not available. Source: (ITU, 2013)

Table 2. Broadband mobile service indicators for developed and developing countries and the world (penetration rates)

Countries	Per 100 inhabitants			
	2010	2011	2012 <sup>a</sup>	2013 <sup>a</sup>
<b>Active mobile-broadband subscriptions</b>				
Developed	42.9	55.1	63.3	74.8
Developing	4.4	8.2	13.3	19.8
World	11.3	16.6	22.1	29.5
Africa	1.8	4.7	7.1	10.9
Arab States	5.1	10.8	14.3	18.9
Asia and Pacific	7.4	11.2	15.8	22.4
CIS	22.3	31.3	36.0	46.0
Europe	28.7	36.6	50.5	67.5
The Americas	22.9	33.6	39.8	48.0

<sup>a</sup>Estimate. Rounded values. N/A: Not Available. Source: (ITU, 2013)

Table 3. Auctions of AWS-1 licenses in the 1710-1720-/2110-2120-MHz frequency bands

Block	Frequency bands (MHz)	Bandwidth (MHz)	Number of licenses
A	1710-1720/2110-2120	20	734
B	1720-1730/2120-2130	20	176
C	1730-1735/2130-2135	10	176
D	1735-1740/2135-2140	10	12
E	1740-1745/2140-2145	10	12
F	1745-1755/2145-2155	20	12

Source: (FCC, 2006)

Contest documents regarding the allocation of spectrum for LTE indicate the technical feasibility of allocating the spectrum to four operators (GKRCH, 2011). The Analysys Mason Report of 2010 indicated the possibility of allocating the Digital Dividend spectrum to three operators. Later, the Russian regulator (GKRCH, 2011) determined the possibility of allocating the spectrum to four operators by reducing the bandwidth in the Digital Dividend from  $2 \times 10$  MHz to  $2 \times 7.5$  MHz and by adding a spectrum in the 2500-2690-MHz range ( $2 \times 7.5$  MHz) (Table 4).

To date, spectrum refarming for 3G (2G→3G) has not been regulated by the Russian regulator, although refarming for 2G→4G at 1800-1900-MHz is relevant. Subject to the sub-federal spectrum allocation contests held in Russia in 2007 and 2011, the RFs in this band were allocated to GSM mobile communications. This range is wide and free from other radio-electronic services (Glushko *et al.*, 2010).

In accordance with the Analysys Mason scenarios, an average of three broadband access providers exists in the rural areas and four in the urban areas (AM, 2010). The four urban operators comply with the standard model of 2G communication development in Russia and with the Analysys Mason scenarios. However, in under populated regions (rural and urban), typically one to two regional (or sometimes) federal operators are licensed, which conflict with the Analysys Mason scenarios. Subject to the contest conditions (Roskomnadzor, 2012), the LTE network should cover approximately one-third of the Russian administrative regions by the end of 2015 [16]. However, no clear option for the LTE is available from the Analysys Mason scenarios.

The Analysys Mason scenarios (AM, 2010) indicated that most of the additional amount from the relocation of ARNS comes from the additional consumer surplus in the rural areas. The conditions of the 2012 LTE contest state that LTE network deployment applies to all localities with 50,000 or more people. However, it is possible that LTE may be deployed neither in populated areas (with  $\geq 50,000$  people) [17], nor in under populated areas ( $< 50,000$  people). In this context, the assumption of the Analysys Mason scenario (i.e., that consumer surplus in a rural area will substantially contribute to the additional amount) rarely holds. The consumer surplus in the rural area will not exceed that in urban areas and the total added amount will be less than the cost of ARNS relocation [18]. The level of 3G development in Russia is rather high [19]. However, 3G is mostly available to the urban population. If we do not consider network development along the major (motor and railroad) lines, then LTE deployment in the rural areas is a problem.

### *The 2012 LTE Contest in Russia*

In 2011, the Russian regulator identified the 791-862-MHz (Digital Dividend), 2500-2690-MHz and 2300-2400-MHz bands for LTE and recommended that the 694-876-MHz band (Digital Dividend-2) be expanded for LTE use (GKRCH, 2011). The regulator established  $2 \times 30$  MHz as the minimum level of spectrum availability for each operator for the LTE, thereby limiting individual operators to four licenses. In the Digital Dividend range, the band for a single operator was set to  $2 \times 7.5$  MHz. The spectrum would be allocated in the form of a contest for the lots shown in Table 5. Licenses would be valid for 7 to 10 years, with the operators being required to invest in LTE deployment during the first 7 years.

### *Coordination of ARNS and MCS in RCC and CEPT Countries in the Transition Period*

In accordance with the WRC-06, the Digital Dividend spectrum will be allocated to the MCS in all Region 1 countries starting June 17, 2015. Subject to RR para. 5.312, the Digital Dividend band is allocated to the ARNS in the 19 CIS and Central and East European countries until 2015 (ITU, 2012a). An expert examination of the technical compatibility of the LTE and ARNS systems by the ITU [20] provided pessimistic data with regard to the joint use of spectrum by the MCS and ARNS in near-boundary countries [21].

Members of the CEPT and RCC met at the WRC-12 Conference Preparatory Meeting (ITU, 2011) to discuss the development of MCS technology in Region 1. Near-boundary countries were recommended to conclude bilateral agreements (Zheltonogov, 2012). Because of the non-uniform geographic distribution of the MCS and ARNS infrastructures, the high level of effect of the MCS on ARNS in each country and the uncertainty of the MCS network parameters, bilateral negotiations [22] were proposed to be held between neighboring CEPT and RCC countries. Agreements were made to allow the CEPT countries to start LTE deployment before 2015 (Table 6). Moreover, as ARNS is located in the lower band of the Digital Dividend-2 (694-790 MHz), the well-timed development of the LTE technology was permitted in this range.

### **LTE Spectrum Allocation Contest in Russia**

#### *Digital Dividend Spectrum Characteristics in Russia and CIS*

The selection of a spectrum band for the LTE depends on propagation characteristics and spectrum availability. RFs below 1GHz are recommended to be used at greater distance in rural areas and remote territories, while a higher RF range is to be used in more populated urban territories.

Table 4. Frame conditions for spectrum reallocation for broadband mobile communication in Russia

Range	LTE contest (2012)				Analysys Mason scenarios (2010)			
	Bandwidth	Spectrum for one operator (MHz)	No. of operators	Wideband spectrum for all operators (MHz)	Bandwidth	Spectrum for one operator	No. of operators	Wideband spectrum for all operators
Digital dividend	2×7.5 MHz	15	4	60	2×10	20	3	60
2500-2690 MHz	2×10 MHz	20		80	2×7.5	15		45
Digital Dividend-2	2×7.5 MHz	15		60	2×7.5	15		45
Total				200				150

Table 5. Allocated RF bands for LTE

Spectrum bands	Lot I	Lot II	Lot III	Lot IV
Spectrum allocated on competition basis	791-862-MHz band	791-798.5/832-839.5 MHz	798.5-806/839.5-847 MHz	806-813.5/847-854.5 MHz
Additional “non-competitive” allocated spectrum	2500-2690-MHz band	2,560-2570/2,680-2690 MHz	2540-2550/2660-2670 MHz	2530-2540 / 2650-2660 MHz
	720-791-MHz band	727.5-735/768.5-776 MHz	720-727.5/761-768.5 MHz	742.5-750/783.5-791 MHz

Table 6. RCC and CEPT countries agreements on coordination of ARNS and mobile service

	BUL	D	DNK	EST	FIN	HNG	LTU	LVA	NOR	POL	ROU	S	SVK	TUR
ARM														C
AZE														C
BLR							C <sub>ARNS</sub>	C <sub>ARNS</sub>		C <sub>ARNS</sub>				
GEO														C
KAZ														
KGZ														
MDA														
RUS	C (TDD)	C (TDD)	C (FDD)	C <sub>ARNS</sub>	C <sub>ARNS</sub>		C <sub>ARNS</sub>	C <sub>ARNS</sub>	C <sub>ARNS</sub>	C <sub>ARNS</sub>		C (FDD)		C (TDD)
TJK														
TKM														
UKR							C <sub>ARNS</sub>			C <sub>ARNS</sub>	C <sub>WRC12</sub>		C <sub>ARNS</sub>	C <sub>ARNS</sub>
UZB														

Agreement not required; C: ARNS agreement required; C<sub>TDD</sub>: ARNS agreement required in case of TDD frequency division; C<sub>FDD</sub>: ARNS agreement required in case of FDD frequency division; C<sub>ARNS</sub>: Agreement concluded before WRC-12; C<sub>WRC12</sub>: Agreement concluded at WRC-12; ARM-Armenia, AZE-Azerbaijan, BLR-Belarus, BUL-Bulgaria, D-Germany, DNK-Denmark, EST-Estonia, FIN-Finland, GEO-Georgia, HNG-Hungary, KAZ-Kazakhstan, KGZ-Kyrgyzstan, LTU-Lithuania, LVA-Latvia, MDA-Moldova, NOR-Norway, POL-Poland, ROU-Romania, RUS-The Russian Federation, S-Sweden, SVK-Slovakia, TJK-Tajikistan, TKM-Turkmenistan, TUR-Turkey, UKR-Ukraine, UZB-Uzbekistan. Source: RCC

The Digital Dividend is ideal for 4G LTE development in Russia because it complies with international approaches to spectrum usage and prioritizes spectrum usage at the lower band. However, during the transfer from analog to digital television, the Digital Dividend band was not being developed in some Central and Eastern European countries, Western, Central and Eastern Asian countries [23] because of its allocation to the ARNS (Glushko *et al.*, 2010) [24]. Moreover, Russia has allocated the upper Digital Dividend band (900 MHz) to the ARNS, resulting in the need for spectrum conversion to reduce the cost of network deployment (but not at higher ranges, e.g., 1800, 2100, 2300-2400 and 2500-2690MHz). Subject to the decision of the Russian regulator (GKRCH, 2011), the 791-862-MHz and 2.5-2.7-GHz bands have been allocated to LTE development. In addition, before the adoption of specific decisions at the international level (WRC-12), the digital dividend-2 was recommended for consideration.

### *Effects of Spectrum Reallocation and Refarming on the Competition Level in Russia*

In Russia, spectrum refarming for the 4G LTE within the frequency range previously allocated to GSM (1800 MHz) is considered an alternative to “physical” spectrum division for the LTE. It is also considered an additional measure of Digital Dividend conversion [25] because the cost of conversion at 761-862 MHz exceeds that of refarming at 1800 MHz. Small regional operators have initiated and supported spectrum refarming and 4G LTE development in Russia.

In terms of industry competition, the refarming in Russia drastically differs from that elsewhere. For instance, in EU countries, regulators anticipate a *higher* concentration of operators in the MCS market after spectrum refarming. The allocation mechanisms for the spectrum market (i.e., auctions) help account for the various values of spectrum ranges (i.e., <1 GHz and >1

GHz) [26]. When non-market spectrum reallocation mechanisms (e.g., refarming) are employed, the spectrum costs may not be indicated in the cost for the recipients (secondary) during spectrum allocation, which can result in increased market concentration (of incumbent spectrum users).

In contrast, the Digital Dividend is reallocated to 761-862 MHz for the LTE [27] in the Russian market, with all license holders obtaining spectrum regions within this range. To ensure high-quality LTE communication, equal spectrum bands within 2.5-2.6 GHz (a less-valued spectrum but with an equal value for all operators) are allocated to the same operators as a bonus. Therefore, the “value” of each spectrum is the same for all winners of the competitive contest [28].

### *Terms and Conditions of the LTE Contest*

Because the Digital Dividend range is currently allocated to other services in Russia, a form of a contest was undertaken to achieve spectrum reallocation.

### *Evaluation Criteria*

In terms of the current activities, the evaluation criteria for the bidders include the following: (1) whether the operator has or is obtaining a valid license for LTE services and to encourage the de-monopolization of the WC market; (2) experience of the operator in providing communications services; (3) any sanctions on the operator by the regulator; (4) any failure to comply with commitments for previous license applications; and (5) length of the fiber-optic network of the operator. The terms and conditions of the contest did not limit the number of licenses owned by a single operator. Thus, formally, one operator could win multiple lots. However, the criterion for the de-monopolization of the WC market downgraded bidders who sought multiple licenses.

### *Future Obligations for Winners*

Winners were obligated to invest in LTE deployment. First, each winner was required to deploy LTE networks at the regional level—specifically, 60 regions in the Russian Federation by 2018—and all regions in their respective lot by 2019. Second, each winner was required to invest at least 15 billion rubles per year (approximately \$457 million) for 7 years in LTE network deployment, for a total of 485 billion rubles (\$15 billion). Third, an expected data transmission rate from the subscriber stations to the LTE base stations was specified. Finally, winners were obliged to connect to Mobile Virtual Network Operators (MVNOs).

In most of the 83 regions in the Russian Federation, the 694-876-MHz and 2500-2690-MHz bands are primarily allocated to non-MCS applications, which limit their availability to the LTE networks. Therefore,

winners of the contest for the Digital Dividend (791-862 MHz) band were required to implement organizational and technical measures to clear the spectrum [29] for the 791-862-MHz, 694-876-MHz and 2500-2690-MHz bands. The cleared bands would be allocated to all winners. Commitments to fund organizational and technical measures were entrusted to the first Russian operator of the LTE network (Scartel) to maintain its existing license for the 2500-2530-MHz and 2620-2650-MHz bands, as well as to the contest winners. The contest winners coordinated the implementation of organizational and technical measures through the LTE Union. Current spectrum users in Moscow and the Moscow Region were compensated for spectrum clearance under the contest terms.

### *Non-Competitive Granting of LTE Licenses*

In addition to receiving a spectrum in the Digital Dividend, the contest winners were granted spectrum in the 2500-2690-MHz band on a non-competitive basis for the LTE for 10 years. A spectrum in the 694-876-MHz band was also allocated. Upon the identification of the Digital Dividend-2 for MCS use by the WRC-12 (ITU, 2012b), the regulator indicated that winners would be given a spectrum in the 720-750-MHz and 761-791-MHz bands (Table 5).

### *LTE Deployment Possibilities for Small- and Medium-Sized Operators*

Winners were required to provide LTE services for MVNO use. Because the frequencies are limited, the application of this technology will enable small- and medium-sized regional operators without a license for the spectrum to provide LTE services. Simultaneously, this technology permits cost reduction for large operators by sharing communication networks. However, each winning operator will be guided by profitability considerations during the allocation of its own capacities to potential competitors for the technology. Furthermore, the execution of accepted future commitments by contest participants is traditionally regarded as rather problematic (FE, 2006; OECD, 2001).

### *Qualifying Applicants and Winners*

Eight applicants qualified for the contest. Six applicants were operators with Russian equity: Mobile TeleSystems (NYSE: MBT), MegaFon (RTS: MEGF), VimpelCom (NYSE: VIP), Rostelecom (RTS: RTKM), Summa Telecom and TransTeleCom. Two applicants were Russian divisions of Tele2 AB (NASDAQ: TLTO), a Swedish telecommunications company (Tele2-Voronezh and Tele2-Omsk). The first three participants (the “Big Three”) are the three largest mobile operators in Russia. Rostelecom has a monopoly in fixed-line services but has recently begun to develop its wireless

services market. Summa Telecom and TransTeleCom are the “outsiders” of the contest. The winners of the contest, namely, Rostelecom (Lot I), Mobile TeleSystems (Lot II), MegaFon (Lot III) and VimpelCom (Lot IV), become Russia’s largest mobile operators (Lots II-IV) and the largest provider of fixed-line broadband services (Lot I).

The Tele2 Russian subsidiary showed some inconsistent actions during the contest. The company filed two separate applications (Tele2-Voronezh and Tele2-Omsk) for the contest. Based on the many considered evaluation criteria, applications from operators with better network infrastructures and longer experiences would have been preferred in the evaluation. As a result of these and other informal circumstances, Tele2 did not achieve a competitive position.

Two participants in the LTE contest (MegaFon and MTS) and a third operator (Scartel, a former WiMAX network operator) received additional spectrum bands. These three operators were previously licensed for non-LTE technology and the regulator obligated them to reform the spectrum. Another operator (Osnova Telecom) received a national license for LTE in the 2300-2400-MHz band for primary use in the public sector (GKRCH, 2009). However, subject to the existing spectrum allocation in the Russian regions, this band can only be used in 40 regions.

### *Analysis of LTE Spectrum Allocation Scenarios and the Need for Spectrum Conversion*

#### *Spectrum Allocation Scenarios*

Although the desire of the regulator to stimulate the development of communications (including spectrum conversion) through private, rather than public, funds is understandable, the implementation of this idea may result in different scenarios. We consider three possible scenarios. Given the commitments assigned to the winners to release the occupied spectrum for the LTE, the regulator-adopted *Scenario 1* can be roughly described as *Spectrum in exchange for spectrum conversion*. According to this scenario, the spectrum release should be cleared by the new licensees. *Scenario 2* can be defined as *Spectrum allocation after conversion*. According to this scenario, spectrum conversion should be done before spectrum allocation procedures (auction, contest and lottery). In *Scenario 3*, *spectrum allocation (auction, contest and lottery) is used to fund spectrum conversion*.

#### *Comparison of the Scenarios*

The scenarios are compared according to three key criteria: Funding for spectrum conversion, qualitative examination of spectrum conversion and spectrum auction proceeds versus spectrum conversion costs.

*Funding for spectrum conversion.* The costs of spectrum conversion for the LTE are estimated at 86 to 100 billion rubles (\$2.6-3.0 billion), sufficiently high to support the industry (in the Scenario 2 case). However, by considering the importance of the issue for the development of the national economy and the potential for the partial (or full) compensation of these costs utilizing a good revenue-generating tool (e.g., spectrum auction), the initial public funding of spectrum conversion appears quite reasonable.

*Qualitative examination of spectrum conversion.* The professional skills of Russian experts in communication are sufficient to provide expert support during spectrum conversion (Kalugin, 2012; Tsvetkov *et al.*, 2012).

*Spectrum auction (contest and lottery) proceeds versus spectrum conversion costs.* The possibility of compensation for spectrum conversion costs largely depends on how economically spectrum conversion can be executed by the public sector. Given the novelty and uniqueness of the spectrum conversion problem for LTE deployment, it would be problematic for the public sector to entirely contribute to spectrum conversion expenditures. To reduce the costs of spectrum conversion, private contractors might be involved on a bidding basis (tender procedures for spectrum conversion) to implement this task. These contractors could be the same contest winners. However, the participation of these contractors should not be associated with the results of spectrum allocation, as would be the case in the last two scenarios and should increase competition and the efficiency of spectrum use.

The LTE contest provided operators with the volumes of spectrum shown in Table 7. One major player (Scartel) was also allowed to use the existing 2500-2690-MHz range after the WiMAX→LTE spectrum refarming. Considering its well-developed infrastructure, Scartel was more prepared than the other operators to deploy the LTE networks (the deployment project was successfully implemented in 2012).

#### *Need for Spectrum Conversion*

As of the end of 2013, no federal program has yet been approved for relocating the ARNS from the Digital Dividend and for deploying the LTE networks (based on the contest results) in Russia. In 2012, the Russian regulator proposed a public-private partnership mechanism for ARNS relocation: The private sector (operators) would be responsible for organizational and technical measures for the ARNS migration (as agreed in the terms of the LTE spectrum allocation contest), whereas the regulator (government) would allocate the spectrum (freed from the ARNS) to the operators. However, because of the role of the private sector, this approach was inconsistent with the Russian legislation.



Table 7. Key parameters of spectrum allocation-obtaining licenses for LTE standard

Band(MHz)	Duplex	Operators				
		Rostelecom, SkyLink	Mobile TeleSystems (MTC)	VimpelCom	MegaFon	Scartel (Yota)
Digital Dividend 791-862 MHz	FDD	791-798.5/ 832-839.5 MHz 2×7.5 MHz	798.5-806/ 839.5-847 MHz 2×7.5 MHz	813.5-821/ 854.5-862 MHz 2×7.5 MHz	806-813.5/ 847-854.5 MHz 2×7.5 MHz	
2500-2690 MHz	FDD	2560-2570/ 2680-2690 MHz 2×10 MHz	2540-2550/ 2660-2670 MHz 2×10 MHz	2550-2560/ 2670-2680 MHz 2×10 MHz	2530-2540 / 2650-2660 MHz 2×10 MHz	
	FDD					2500-2530/ 2620-2650 MHz, <sup>a</sup> 2×30 MHz
	TDD		2595-2620 <sup>a</sup> 25 MHz		2570-2595 <sup>a</sup> 25 MHz	
Digital Dividend-2 720-750 and 761-791 MHz	FDD	727.5-735/ 768.5-776 MHz 2×7.5 MHz	720-727.5/ 761-768.5 MHz 2×7.5 MHz	735-742.5/ 776-783.5 MHz 2×7.5 MHz	742.5-750/ 783.5-791 MHz 2×7.5 MHz	

<sup>a</sup>Based on spectrum refarming for LTE network deployment. Sources: (GKRCH, 2011; Roskomnadzor, 2012; CSL, 2011)

Therefore, the regulator proposed other short- and long-term goals in 2013. The short-term goals (through 2016) are to provide electromagnetic compatibility of the commercial and government systems and to ensure coverage in several Russian administrative regions. The long-term goals (through 2020) include the direct relocation of governmental systems and the coverage of the entire territory in Russia (GKRCH, 2013). The regulator-initiated activities in 2013 were aimed at improving the efficiency of spectrum use (e.g., through cognitive radio and time separation of channels). In preparation for the Sochi Winter Olympic Games, the relocation of the ARNS and spectrum freeing for the LTE are only implemented in Sochi, with the spectrum freed in the Digital Dividend band (2×25 MHz) (GKRCH, 2013).

## Conclusion

In Russia, the LTE spectrum allocation process was largely controlled by the regulator from the moment the general principles of the LTE contest were defined up to the time when contest results were made available. In particular, the pre-contest decision of the regulator to limit the number of participants to four operators was consistent with the overall logic of deciding the potential winners. The subsequent formulation of the evaluation criteria provided the most probable win for the incumbents. For example, the inclusion of the length of the fiber-optic line as a criterion was instrumental in permitting the incumbents to obtain the maximum number of points. This criterion was proposed in 2011 by the LTE Union (comprising representatives of the same operators) during the public hearing for the contest design. The official decision of the regulator on LTE deployment contained a statement in support of the proposal of the LTE Union.

The de-monopolization criterion in the contest conditions was partially achieved; however, the problem of improving competition in the industry remained unresolved.

Spectrum contests can generate large revenues, but the initial terms and requirements of the Russian LTE contest (2012) did not consist of money assessments—which was why the operators did not make traditional bids. Instead, the regulator evaluated the qualitative characteristics and expertise of the operators to realize spectrum conversion (ARNS migration). Considering the above-mentioned condition, the LTE contest (2012) could be considered as hybrid procurement and spectrum contests rather than a standard spectrum contest. The absence of money assessments in the terms and conditions of the contest was stipulated by the motivation of the regulator to stimulate WC development, indirectly benefiting MCS penetration (Table 1 and 2) and the collusion of incumbents (in the form of the LTE Union). This stipulation was provided by the terms of the LTE contest, which were realized in the decision of the regulator (GKRCH, 2011).

The ARNS migration mechanism proposed by the Russian regulator in the LTE contest was based on “extensive” spectrum usage and was similar to the logic of the U.S. CSEA. “Intensive” spectrum usage (e.g., cognitive radio and digital modulation) was also considered by the regulator but for a longer-term period than the LTE contest.

## Notes

[1] Digital Dividend refers to the amount of spectrum in the very high frequency and ultra-high frequency bands, which is above the amount nominally required to accommodate existing analog television programs and which might be freed in the switchover from analog to digital television (p.12 in (infoDev and ITU, 2011)).

[2] Region 1 includes Europe, Africa, some Middle Eastern countries, the former Soviet Union and Mongolia.

[3] Para 5.316A and 5.316B of Radio Regulations (RR).

[4] For countries specified in para 5.312 of RR

[5] Subject to para 5.312 of RR.

[6] "The price of providing mobile broadband using the 700/800 MHz band is approximately 70% lower than that of providing services using the 2100 MHz band." (Cabello, 2009).

[7] "Rather than to forcibly clear spectrum and create perverse post-auction relocation-compensation games, which poorly impact auction values and jeopardize the start-up of new services, the FCC should use something like a procurement auction to acquire a voluntary supply of spectrum from current licensees and then auction it off... The bid and offer markets can be combined into a single double-sided auction where bids and offers are made simultaneously." (De Vany, 1998).

[8] In particular, De Vany compared the spectrum auction mechanism with the stock market initial public offering.

[9] For example, cognitive radio.

[10] Relevant funding procedures for the relocation of government spectrum users were also implemented in Japan and India (please see (Manero *et al.*, 2006)).

[11] Cost of network maintenance, construction and infrastructure maintenance (base stations, etc.).

[12] Refarming characterizes a "process of any basic change in conditions of frequency usage." (infoDev and ITU, 2011)

[13] The Analysys Mason study was conducted 5 years before the date of termination of ARNS protection.

[14] For a conceptual framework of this auction, please see (Kwerel and Williams, 2002).

[15] Spectrum conversion is defined as the reallocation of the spectrum owned by government users to civil users. Subject to Russian federal legislation, RF spectrum conversion entails a package of measures intended to extend the use of the spectrum through civil radio-electronic equipment (RG, 2003).

[16] Two Russian operators own 20 administrative regions each, a third operator owns 22 regions and a fourth owns 25 regions. This requirement applies to each populated area with  $\geq 50,000$  people.

[17] Complying with the terms and conditions of the contest is difficult because of the potential non-fulfillment of obligations by the competitors and monitoring difficulties (please see, for example, the spectrum allocation contests held in Sweden (2001) and Spain (2000) (FE, 2006).

[18] The regulator estimated the cost of ARNS reallocation to be \$2.6-3.0 billion.

[19] Please see Table 2.

[20] Expert examination data are included in the WRC-12 Conference Preparatory Meeting Report (ITU, 2011).

[21] The required coordination distance for MCS systems are from 50 to 450 km, depending on the noise scenario, because of the uncertain characteristics of future MCS systems, uncertain frequency plans and the inability to know the actual conditions in each country (e.g., station density and signal propagation paths) (Zheltonogov, 2012).

[22] For example, between CEPT and RCC.

[23] Subject to para 5.312 of the RR (ITU, 2012), Armenia, Azerbaijan, Belarus, Bulgaria, the Russian Federation, Georgia, Hungary, Kazakhstan, Moldova, Mongolia, Uzbekistan, Poland, Kyrgyzstan, Slovakia, the Czech Republic, Romania, Tajikistan, Turkmenistan and Ukraine.

[24] Given the high cost of ARNS relocation to other frequencies, the term "digital divide" can be considered appropriate.

[25] Subject to the decision of the Russian regulator, Digital Dividend will be reallocated to support harmonization with international communication services.

[26] However, even auctions do not provide equal conditions because incumbents enjoy the economies of scale, tend to prevent new competitors in the market and maintain high market prices, have an advantage in their own brands and have advantages owing to the expected return of investment to the spectrum infrastructure and license (Lundborg *et al.*, 2012).

[27] i.e., <1 GHz.

[28] Not for all bidders.

[29] Mainly ARNS migration, in the form of refarming, spectrum conversion, spectrum relocation of current users, etc.

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## Ethics

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