Seminar on pricing for frequency usage for CIS Countries
Yerevan (Armenia), 21-23 March 2001

B. Nurmatov

Evaluation of the national Spectrum used, proceeding from the presenting it as the three-dimensional radio frequency-spatial-time resource

Traditional way of payment for spectrum, got in inheritance from the former USSR and hitherto aplicable in number of the CIS countries, based on application of approved price-list, in which price gradations, basically hang from radio services type and transmitter power.

This is sufficiently simple way of financing and was efficient in the USSR during development of fixed and broadcasting services, number of types of aplicable radio electronic means was extremely limited, and renovation of equipment was realized slowly.

In these conditions a formation and approving of a Price-list did not form the greater problems, but duration of its action was within ten years.

Main defect of the method:

- Price-list did not reflect real frequency resource used;
- A charge was defined by actually aplicable equipment and did not stimulate an efficient spectrum use;
- Price-list did not reflect varieties of aplicable and introduced new radio technologies and did not give energy to administrations in the determination of spectrum price at the appearance on the market of new equipment.

Attempts to adapt a method to the all variety of aplicable at present radio electronic means, brought to a sharp increasing of Price-list volume, but its development and statement changed in unceasing, labour-consuming process, in addition, price-list to a moment of its adoption already grew old.

It is appeared a posibility to abstract from the variety of spectrum use, if enter a notion of spectral resource and if it is possible to evaluate the resource in quantitative way.

In the 60-s of the ?? century the notion of three-dimensional value of spectral resource was introduced, depending on the frequency band used, on the territory and on a time.

If use this notion, for any *i*-th frequency assignment in the national database the three-dimensional value of the spectral resource, denoted as Z_i, is to be determined as follows:

$$Z_i = Fi \times Si \times Ti \qquad (5)$$

Where:

Fi – frequency resource

Si – territorial resource

Ti – time resource

Determination of a Time Resource Used by an Emission

A time resource T_i used by i -th emission is determined as:

$$T_i \leq 1 \text{ (year)} \qquad (6)$$

And for each frequency assignment represents a fraction of time related to one year, determined in that or another way, during which the radio transmitter operates in accordance with terms set out in the relevant license.

For example,

- If particular TV transmitter in accordance with terms of its license is operating only 16 hours per a day throughout the whole year, than: T_i = 16/24 = 0.67 year.
- If another transmitter (for example an HF one used for geological expedition), in accordance with terms of its license can operate totally only 3 month per a year, than: T_i = 3/12 = 0.25 year.
- If transmitter which operates permanently, for example a radio relay station, T_i = 1 year. The last situation is usually typical for the majority of frequency assignments presented in any national Spectrum Management Database. Such a regime is the most commonly requested and licensed.

Determination of a Territorial Resource Used by an Emission

Emission of any i-th transmitter occupies some territory λ_i (km^2), which area will be a function of features of its frequency assignment, i.e.

λ_i = f (Pi, ? $_i$, Di, Ri) (km^2),

where:

Pi – radiated power;

H_i – efficient antenna height;

D_i – diagram of antenna directivity;

R_i – particularities of terrain relief

If we take value λ_i as a territorial resource , for one and same transmitter value of territorial coefficient of spectral resource in large city and in sparsely populated area will be the same, which does not correspond to a reality.

To take this factor into account it is possible enter certain amount of m territorial categories and to install weighting coefficient bj for each j-th category ($i \leq j \leq m$).

The number of categories *m* and the relevant values of the weighting coefficients b_j should be set out by a National Telecommunications Administration.

These categories can take into account density of population and/or level of economic (industrial and/or agricultural) development of various regions of a country. They represent a measure of attractiveness for radio communication and broadcasting operators. Categories may also distinguish urban and rural areas, inland and coastal areas, mainland and island areas. Additionally settlement type and number of permanent or transitory inhabitants could also be included.

Illustrative examples are presented in Tables 1 and 2.

Table 1

Table of account of a density of population on various territories of the Kyrgyz Republic

Name of an area (oblast)	Bj
Naryn	1
Talas	3,7
Issyk-Kul	3,5
Jalal-Abad	5,6
Osh	5
Chuy	8
Cities and settlements of an urban type	
- With a population of 10 000 to 50 000 inhabitants	16
- With a population of 50 000 to 100 000 inhabitants	32
- With a population of 100 000 to 500 000 inhabitants	64
- With a population over 500 000 inhabitants	128

Territory actually occupied by the emission, λ_i is calculated separately for each emission i on the basis of relevant service area concept with using nominal usable field strength $?_n$ at its borders. There are some procedures of calculation, applicable to various radio services.

Table 2

Example of weighting coefficients taking into account a density of population (a level of economical development) in various regions of a country

	Designation	b_j
1	The less populated and/or the less economically developed regions (deserts, high mountains, deep jungles etc.) which are usually the less attractive for radiocommunication and broadcasting operators	0.1
2 – *j* - …	Regions with several intermediate and increasing gradations of density of population and/or indicators of economical development	0.2 – 0.9
…..	The most populated and/or the most economically developed regions (capital region, main industry and/or agricultural areas etc.) which are the most attractive for radiocommunication and broadcasting operators	1
Cities and settlements of an urban type		
….	With a population of 10 000 to 50 000 inhabitants	1.2
….	With a population of 50 000 to 100 000 inhabitants	1.5
m - 2	With a population of 100 000 to 500 000 inhabitants	2.0
m - 1	With a population of 500 000 to 1 000 000 inhabitants	3.0
m	With a population over 1 000 000 inhabitants	4.0

As a rule, territory λ_i is calculated in the course of carrying out such technical functions of spectrum management, as determination of service area and coordination area, EMC calculation and for solving a problem of determination of spectrum price it is simply to use results of these calculations.

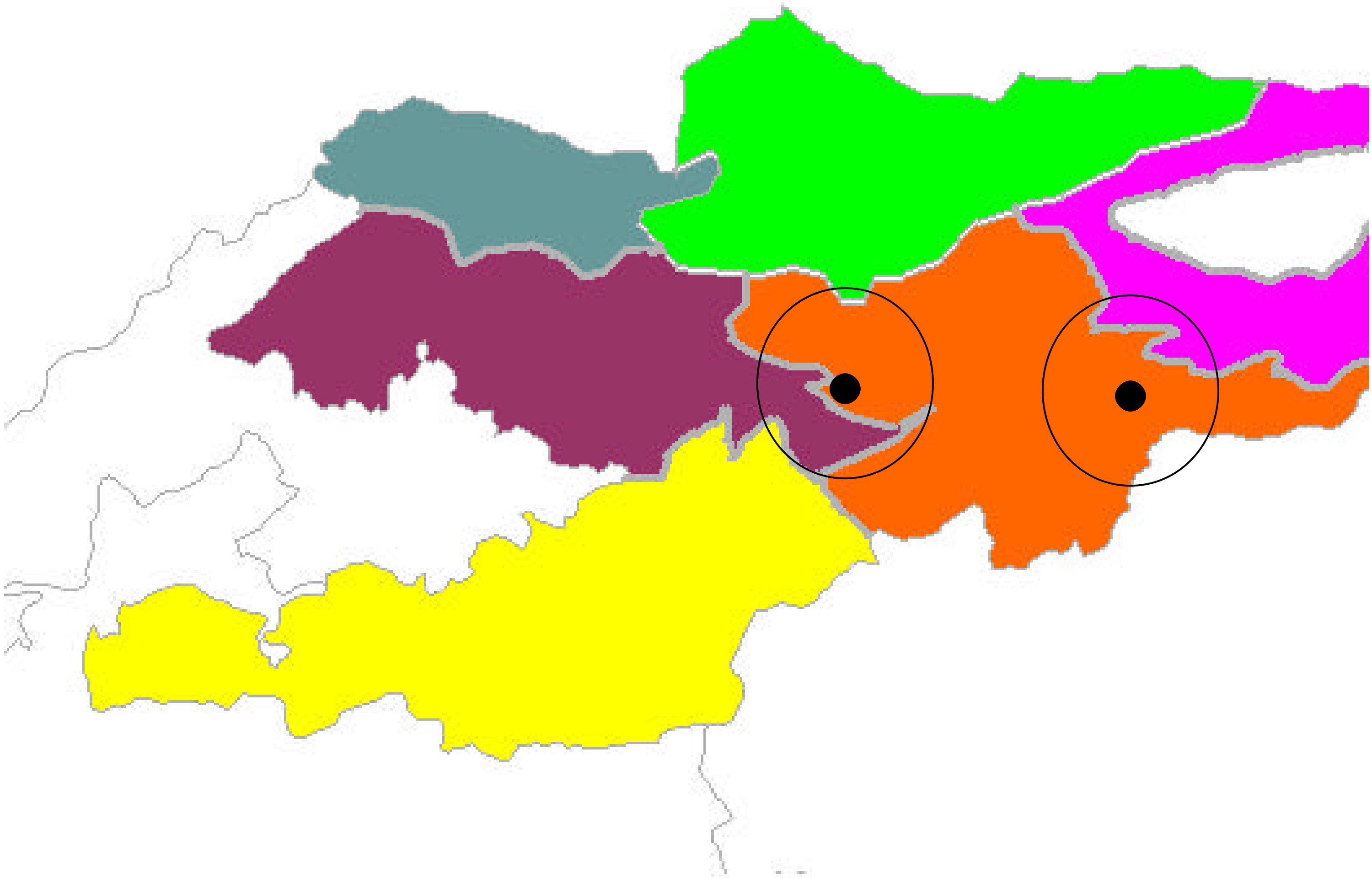
Problem can be more simplified and be solved more exactly, if administration uses geoinformational system and software, allowing determine service areas.

Thereby, knowing service area (or coordination area) and territory λ_i, used by i-th emission, have approved categories for each territory of the country, weighting coefficients for these categories, it is possible to begin the determination of territorial coefficient of spectral resource.

Territorial resource Si , used by the emission i, is defined as follows:

$$S_i = b_{i,j}\,\lambda_i \text{ (km}^2\text{)} \qquad (7)$$

$$1 \le j \le m$$



where: λ_i – territory, actually occupied (or covered) by the emission, km^2

$b_{i,j}$ – weighting coefficient which depends on the *j* -th category of the territory actually occupied by the emission

m – number of categories

But by the formula (7) it is possible to determine a territorial resource S_i only when territory λ_i lies within one region, having one category and, accordingly one weighting coefficient.

If territory, practically occupied by the emission i, includes several regions p, g,…k, belonging to the different abovesaid categories, relevant territorial resource can be determined as follows:

$$Si = \sum_{j = p,g,\dots k} b_{ij} \times \lambda_{ij} \qquad (8)$$

where:

b_{ij} – relevant weighting coefficient for the category j = p,g,…k of territory, entered to the territory, occupied by the emission i

λ_{ij} – relevant j-th part of the whole occupied territory λ_i

Usually the number of regions with different categories, falling into one territory λ_i of the emission i, doesn't exceed 3.

Determination of a spectral resource frequency component used by the emission

A frequency resource F_i used by *i* -th emission is determined as

$$Fi = \alpha_i \times \beta_i \times \Delta f_i \text{ (MHz)} \qquad (9)$$

where:

α_i – general weighting coefficient, that counts several factors as commercial value, social value etc.

β_i – weighting coefficient determining exclusiveness of use;

Δf_i – frequency band, which is accounted in payment for the i-th frequency assignment.

$$\Delta f_i = \chi \times \Delta f \qquad (10)$$

where:

Δf - necessary bandwidth of the emission in MHz. Usually Δf is determined from the users request, when he requests a frequency assignment; the necessary bandwidth can be calculated in accordance with Recommendation ITU-R SM.1138 (see Radio Regulations, Geneva 1998, Volume 4), taking into account that an occupied bandwidth of an emission should be equal to its necessary bandwidth (Recommendation ITU-R SM. 328-9)

χ - adjustment factor ($0 \le c \le 1$) can be used in some cases, for example, to decrease somewhat a very great difference in fees between sound and TV broadcasting, under the same powers of transmitters, due to significant difference in the necessary bandwidths. It also can be used in cases of radar applications.

β_i- weighting coefficient. It determines the exclusiveness of frequency assignment. If given site of a spectrum is used on exclusive basis, then $\beta_i = 1$. In mutual usage β_i is varied within 0 to 1 depending on conditions of combining.

α_i - General weighing coefficient in formula (9) can be presented as a product of the following fractional coefficients:

$$\alpha_i = \alpha_1 \times \alpha_2 \times \alpha_3 \times \alpha_4 \times \alpha_5 \qquad (11)$$

where:

α_1 takes into account commercial value of the spectrum range used

a_2: taking into account social factor

a_3: takes into account features of transmitter location

a_4: takes into account the complexity of spectrum management functions

a_5: other coefficient (coefficients) which can be introduced by an Administration reflecting its specific needs.

Illustrative examples of these coefficient values are presented in Tables 3 and 4.

Coefficient a_1 is basically determined by two factors:

- The commercial value of radio services. This factor is linked to the willingness of users and operators to pay for the right to provide services or use the services operated over a specific frequency
- The necessity of using less congested (usually – higher) frequency bands. Some radio services may be moved to higher frequencies as experience is gained or a technology changes. Thus, decreasing the loading of lower frequency bands. This is the economic lever which should encourage usage of higher bands.

Coefficient a_2 takes into account a social factor. For those radio services, whose existence is vital for all groups of the population, including the most needy, this coefficient has a low value reflecting a truly social value or obligation on behalf of the Administration.

For example, for microwave stations above 1 GHz, through which long-distance communications are provided, as well as for television broadcasting, the coefficient a_2 has a low value and for cellular communication, coefficient a_2 has a higher value.

Coefficient a_3 takes into account features of site location in urban and village conditions. In village conditions, where the density of the population is low and the level of the incomes is also low, the commercial value of communication services will also be low, at the same time technological costs for providing these services will also be high. Therefore with the purpose of support of the telecommunication operators and services as well as for encouraging development of radio communication services this can be a lower coefficient a_3, while in urban districts it may be considerably higher.

Coefficient a_4 is determined by the complexity of spectrum management functions performed. This coefficient is usually the highest for mobile services. It is here that it is required to carry out the function of radio determination of mobile objects. Likewise for television broadcasting, it is required to determine with a high degree of accuracy a number of relevant parameters.

Thereby, proceeding from three-dimensional frequency-spatial-time specrtal resource presentation, in accordance with formulas (5), (6), (8), (9), as well as using relevant tables of weighting coefficients, **for any i-th frequency assignment** it is possible to determine used spectral resource, and having summarized them on all **n** frequency assignments, keeping in the national database it is possible to get national spectral resource used.

Table 3

Table coefficients

Service \ a_i	α_1	α_2	α_3		α_4
Radio relay line in a range above 1 GHz	0,5	0,30	1	0,	1
Radio relay line in a range below 1 GHz	1	4,00	1	0,1	1
Television in meter range (MW TV)	5	0,30	1	0,1	5
Television in decimetre range (DMW TV)	5	0,40	1	0,1	5
VHF sound broadcasting	12	5,00	1	0,1	5
LF – HF broadcasting	5	5,00	1	0,1	4
HF radio communications	13	6,00	1	0,1	4
Trunking	12	6,00	1	0,1	5
Cellular	13	6,00	1	0,1	5
Paging	60	6,00	1	0,1	5
PMR communications	10	6,00	1	0,1	5
Radio communications in CB range	0,12	1,00	1	0,1	1
Radiolocation	0,15	0,10	1	0,1	1
Aeronautical radio comm. and navigation	6	1,0	1	0,1	2
Maritime radio communication	40	1,00 0,30*	1	0,1	1
Earth station for fixed satellite service	7	0,30	1	0,1	1

Note: α_2 * - (coefficient, taking into account social factor) is entered for international organizations, acting on the territory of the Kyrgyz Republic, not presenting commercial services of communication, but activity of which is directed to the assistance of stability of economy, development of science, culture.

Table 4

Table of service depended coefficients

Service \ a_i	a_1	a_2	a_3		a_4
			City	Village	
Radio relay line in a range above 1 GHz	0.1	0.1	1	0.1	0.2
Radio relay line in a range below 1 GHz	0.4	0.2	1	0.1	0.2
Television in meter range (MW TV)	1	0.1	1	0.1	1
Television in decimetre range (DMW TV)	1	0.2	1	0.1	1
VHF sound broadcasting	2.4	1	1	0.1	1
LF – HF broadcasting	1	1	1	0.1	0.8
HF radio communications	2.6	1.2	1	0.1	0.8
Trunking	2.4	1.2	1	0.1	1
Cellular	3	1.2	1	0.1	1
Paging	3.5	1.2	1	0.1	1
PMR communications	2	1.2	1	0.1	1
Radio communications in CB range	0.1	0.2	1	0.1	0.2
Radiolocation	0.1	0.02	1	0.1	0.2
Aeronautical radio comm. and navigation	0.1	0.2	1	0.1	0.8
Maritime radio communication	1	0.2	1	0.1	1
Earth station for fixed satellite service	4	0.2	1	0.1	0.2
Earth stations for other satellite services including feeder links	1.4	0.1	1	0.1	0.2