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# The Calculation Methodology for the Energetic Reserve of the Radio Link Spacecraft-Station

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**Abstract.** Nowadays different sets of calculation methods for energetic reserve are used at the factories of the rocket and space industry, meanwhile, not all the factors influencing the energetics of a radio link are taken into consideration. This causes difficulties while comparing some calculations with others and requires further recalculations, which are different from the previous ones and usually have negative results.
The article given below includes the methodology for a general calculation of the energetic reserve of a radio link transmitting the information from a spacecraft to a receiving station. Most of the methods of evaluating the effect of the atmosphere on the signal can be found in the recommendations of the International Telecommunication Union (ITU). Methods of calculation of the losses caused by the environment, which are kept in the recommendations of the ITU, are complemented by loss accounting methods resulting from the guidance errors, Faraday effect, and receiver noise temperature calculation.

**Keywords:** satellite communication, atmospheric attenuation, radio link "spacecraft-station", energy calculation of a radio link

## Introduction

Development of space systems and space complexes at all stages of a product life cycle demands carrying out calculation of an energy margin of a radio line. At the stage of the preproject, a predesign of an energy margin of the radio line is performed; at the stage of the conceptual design, an analysis of several options of creation of the equipment with calculations of an energy margin of a radio line for each of the options is carried out; at the stage of development of design documentation, a detailed calculation of the chosen option and correction of the calculations by results of ground and experimental development is fulfilled; and at the operational phase, the analysis and confirmation of the carried-out calculations for correction and specification of the applied technique of calculations based on the received statistics is carried out. It is important to understand that the fullest calculation taking into account the influence of the Earth surface and the atmosphere already at the preproject stage will further allow avoiding corrections of requirements imposed to the onboard and ground equipment. Nowadays at the enterprises of a rocket and space industry, there is no uniform technique of an assessment of the influence of losses (atmospheric, polarizing, etc.) arising at signal distribution. The above-stated circumstances cause relevance of an objective.

Use of frequencies for the systems of a radio communication and broadcasting is strictly regulated by the International Telecommunication Union and the State Radio Frequency Commission. Requirements to the increase in the volumes of information transferred from spacecraft lead to the requirement on the increase in speed of information transfer that leads, in its turn, to the increase in a necessary frequency band, and this, taking into account a load of a current frequency plan leads to the increase in the value of a carrier frequency. Each of frequency ranges possesses the specifics of a set of losses at signal distribution, which needs to be considered at calculation. Detailed calculations are necessary not only for the signals with in advance known frequencies, such as GLONASS, AIS (tracking of vessels) and automated dependent observation-broadcasting (ADOB, tracking of aircraft), but also for again developed radio lines: high-speed radio links for transfer of target information and intersatellite radio lines.

An assessment of weakening of a signal becomes especially relevant in view of search of balance between power decrease of radio-transmitting devices and an informational content increase. It is necessary to solve a task of the multicriteria choice of parameters of a radio link for information transfer with the set speed and the reliability satisfying the customer.

The analysis of publications allows one to draw the conclusion that there is no standard technique of an assessment of the influence of the losses (atmospheric, polarization, etc.) arising at signal distribution. A question of an assessment of the influence of the atmosphere on a signal contains most fully in the recommendations of the International Telecommunication Union.

The purpose of the present paper is to show and standardize a technique of calculations of an energy margin of radio lines representing the calculation of a radio line "spacecraft–station".

## 1. Calculation of an energy margin of a radio line

To ensure information transfer with a required speed and a set probability of a bit mistake, it is necessary to analyze physical processes and to carry out calculation of the parameters influencing the distribution of a radio signal in natural radio routes. Within this article, the signal transfer on the radio line "spacecraft–station" is considered.

SC moves in space on the set orbit; a reception of a signal is conducted on a receiving station, which can be located both directly on the ground and at some height over it. From parameters of SC movement, it is necessary to determine the maximum and minimum ranges between SC and the station and elevations under which SC is observed from the station.

Calculations should be conducted for all possible limiting cases: this will permit one to determine the range of changes of power flux density (PFD) in the fold of a receiving antenna forming the requirements to the dynamic range of the receiver. When calculating losses in the atmosphere, one has to analyze the altitude of station location above sea level and make a conclusion whether the Earth atmosphere influences the parameters of a radio signal.

Possibility of signal reception and availability of a radio line are defined by a positive value of an energy margin calculated as a difference between energy potential in the input of a receiving low noise amplifier (LNA) and its sensitivity. Calculation of energy margin

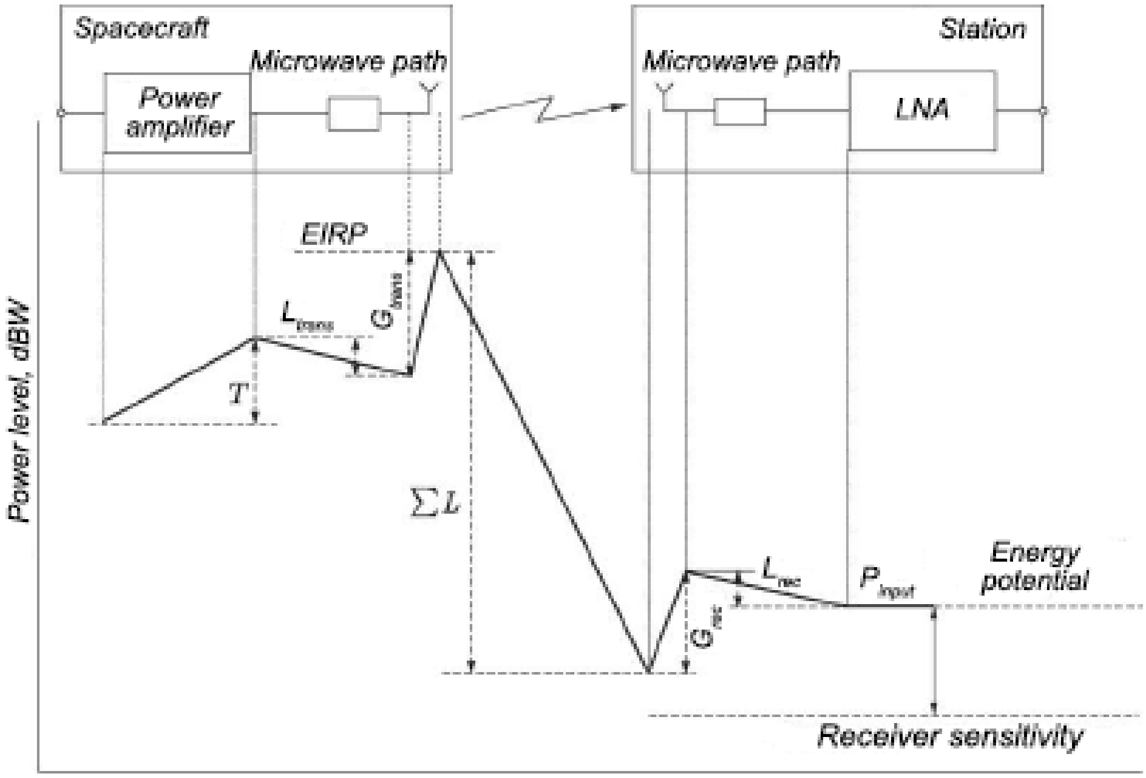


Figure. Structural scheme of the "spacecraft-station" radio link

begins with determination of the value of the equivalent isotropically radiated power (EIRP) of SC and conditions of signal distribution. The block diagram of a "spacecraft (SC)–station" radio line and graphical representation of a power level of a signal is given in the figure.

Transmission begins with SC, EIRP, which is expressed in dBW and calculated as [1]

$$\mathrm{EIRP} = G_{trans} + T - L_{trans}\ (\mathrm{dBW}) \qquad (1)$$

where $G_{trans}$ is the gain of the transmitting antenna expressed in decibels relatively to isotropic gain, dBI; $T$ is the value of power of a signal in the output of the power amplifier, dBW; $L_{trans}$ is the losses in the microwave path from the power amplifier to the antenna input, dB.

During signal propagation, in the medium there takes place damping of wave oscillations in a free space caused by signal spreading when ranging from the transmitter. A signal comes to the receiving antenna of the station with the gain $G_{rec}$ connected with the receiver through a waveguide with the losses $L_{rec}$. The value of signal power $P_{input}$ in the input of a LNA is calculated by the formula:

$$P_{input} = \mathrm{EIRP} - \Sigma L + G_{rec} - L_{rec}\ (\mathrm{dBW}) \qquad (2)$$

where $\Sigma L$ is the value of sum losses; $G_{rec}$ is the gain of a receiving antenna expressed in decibels relative to isotropic gain, dBI; $L_{rec}$ is the losses in the microwave path from the antenna output to the LNA input (all losses have dB regularity).

Comparison of signal power in the input of a LNA with the sensitivity of the $R_x$ receiver determines the target value of an energy margin and radio link availability:

$$Z = P_{input} - R_x\ (\mathrm{dBW}). \qquad (3)$$

Sensitivity is defined by a minimum level of signal power in the input of a receiver when information reception is provided with the required speed and set probability of a bit error. In case when signal power in the LNA input is less than sensitivity of a receiver ($Z < 0$), it is not possible to ensure signal reception with the required validity. If the level of signal power in the LNA input is more than sensitivity ($Z > 0$), then reception is provided with the required validity.

The receiver sensitivity is calculated by the formula:

$$R_x = \kappa + T_{экв} + B + C/N\ (\mathrm{dBW}), \qquad (4)$$

where $k = -228.6 \cdot 10^{-23}$ (dBW/kHz) is the Boltzmann constant; $T_{eqv}$ is the equivalent noise temperature of a system expressed in decibels relative to the value 1 K, dBK; $B$ is the signal bandwidth expressed in decibels relative to the value 1 Hz, dBHz; $C/N$ is the required signal-to-noise ratio, dB.

Formula (4) shows a connection of the sensitivity and the required signal-to-noise ratio in the input of the receiver. As an example: providing of the less value of signal-to-noise ratio in the input of an LNA results in toughening of the requirements to the receiver (decrease in losses in the microwave path, decrease in noise coefficient of the receiving path, etc.).

A ratio of a signal power to noise power recalculated to the input of an LNA is expressed by the equation [1–3]

$$C/N = E_b/N_0 + R - B, \tag{5}$$

where $E_b/N_0$ is the required ratio of the energy of the information bit to the one-side spectral power density of noise for the set validity of reception and speed of data transfer, dB; $R$ is the speed of data transfer expressed in decibels relative to the value 1 bit/s, dBbit/s.

Let us substitute (5) into (4):

$$R_x = k + T_{eqv} + R + E_b/N_0 \text{ (dBW)}. \tag{6}$$

## 2. Technique to calculate equivalent noise temperature of the system

When calculating the value of an energy margin of a radio link, it is important to determine a general power of noises, which are generated in the input of a receiver by different sources — an equivalent noise temperature. An equivalent noise temperature of a system is calculated by the formula [11]

$$T_{eqv} = T_a \cdot L_{rec} + 290 \cdot (1 - L_{rec}) + (F - 1) \cdot 290 \text{ (K)}, \tag{7}$$

where $T_a$ is the noise temperature of an antenna, K; $F$ is the noise coefficient of a LNA's receiver; $L_{rec}$ is the losses in the microwave path from the antenna's output to the LNA's output.

An equivalent noise temperature for the onboard antenna can be presented by the following components:

$$T_{ant} = T_{b.atm} + T_{b.E.} + 2cT_{b.space} \text{ (K)}, \tag{8}$$

where $T_{b.atm}$ is the noise temperature of the atmosphere, K; $T_{b.E.}$ is the brightness temperature of the Erath, K; $T_{b.space}$ is the brightness temperature of the prolonged space sources, K; $c$ is the coefficient considering an average level of side and back lobes of a radiation pattern of the antenna.

An equivalent noise temperature for the ground antenna can be depicted as following:

$$T_{ant} = T_{b.space} + T_{b.atm} + cT_{Earth} + T_{n.cone} \text{ (K)}, \tag{9}$$

$T_{n.cone}$ is the noise temperature due to the influence of a blister of the antenna, K; $T_{Earth}$ is the noise temperature of the Earth radiation, K.

Radiation of the Earth atmosphere has a thermal nature and at full extent is stipulated by signal absorption in the atmosphere. Owning to thermodynamic balance, the atmosphere radiates the same amount of energy at this frequency, which it absorbs. A noise temperature of the atmosphere is determined by the formula:

$$T_{b.atm.} = T_{atm.av.} (1 - 10^{(-A_r - A_c - A_g/10)}) \text{ } (K), \tag{10}$$

where $T_{atm.av.}$ is the average thermodynamic temperature of a standard atmosphere; $A_r$ is the weakening due to hydrometeors, dB; $A_g$ is the weakening in atmosphere gases, dB; $A_c$ is the weakening due to a clouded sky, dB.

A value of an average thermodynamic temperature of a standard atmosphere is given in [4]. A detailed calculation of losses in presented in section 3.4.

Noises of space origin are determined, in general, by radiations of the Galaxy, Sun, and Moon. An average temperature of the noises of the Galaxy is negligibly small in the range of frequencies 6/4 GHz and more and does not surpass several degrees of Kelvin at the frequencies more than 2 GHz at any elevation. At the same time, the radiation of the Sun can completely break communication when falling onto the main lobe of the radiation pattern of the antenna. The radiation of the Moon causes less influence than the noises of the Galaxy, since its noise temperature is several degrees less than the noise temperature of the Sun.

The coefficient considering an integral level of side lobes of the radiation pattern of the antenna is determined by the formula:

$$c = \frac{1}{2} \sum_{i=1}^{n} \int_{0}^{\Omega_{\text{side}i}} G_{\text{side}i}(\alpha, \theta)\, d\Omega \bigg/ \int_{0}^{\Omega_{\text{main}}} G(\alpha, \theta)\, d\Omega, \tag{11}$$

where $G_{\text{side}i}$ is the coefficient of the antenna gain within the limits of back and side lobes; $G$ is the coefficient of the antenna gain within the limits of the main lobe.

A component of the noises of the antenna from the thermal radiation of the Earth $T_{Earth}$ at the elevations of the antenna from 5–7° to 90° is stipulated by its reception of side and back lobes. Due to side lobes, the increase in the temperature of noises of the antenna of the ground station can be approximately estimated by the formula:

$$cT_з = 23 + 0.2(90° – \theta)\ (K) \tag{12}$$

where $\theta$ is the elevation of the receiving antenna, degrees.

For the onboard antenna, $T_{b.Earth = 290}$ K.

In some cases, antennas of ground stations are covered from the influence of precipitations with a radiotransparent blister. Losses of a signal and correspondent augmentation of noises are usually not big and can be almost not taken into account. However, during intensive rains, a water film appears on the surface of a blister, which is a cause of significant absorption of a signal and formation of secondary noises.

## 3. Losses of a radio link

At distribution of radio waves along natural radio routes, the environment influences the characteristics of a radio signal. Apart from losses in a free space, a radio wave passes through additional losses: losses at distribution through the atmosphere, losses because of the antenna pointing error, polarizing losses, losses on the antenna blister, etc.

The general losses $\sum L$ in the radio line are calculated by the formula:

$$\sum L = L_{losses} + At + L_{pol} + L_{point_{trans}} + L_{point_{rec}} + L_{otl}\ (dB) \tag{13}$$

where $L_{losses}$ are the losses in a free space;

$At$ is the general weakening of a radio signal in the atmosphere,

$L_{pol}$ are the polarizing losses;

$L_{point_{trans}} + L_{point_{rec}}$ are the losses caused by the errors of pointing of the transmitting and receiving antennas, dB;

$L_{otl}$ are the other losses caused by the intersymbol interference, hindrances of the neighboring channel, the losses connected with restriction of the band (since all systems use in the filters to transfer energy in a limited or separated band, similar filtration decreases a total quantity of the transmitted energy that leads to weakening), etc., dB.

Further, calculation of all components, comprising the formula, is given (13).

### 3.1. Losses in a free space

Losses in a free space are calculated according to the formula (14) [1–3]:

$$L_{losses}=(4\pi \cdot (d_{trans\text{-}rec}/\lambda))^2, \tag{14}$$

where $d_{trans\text{-}rec}$ is the range of radio communication, m; λ is the wavelength, m.

### 3.2. Losses caused by pointing errors

The losses caused by a pointing error are generated due to inaccuracy of antenna pointing and are considered independently both for transmitting and receiving antennas. The antenna gain is calculated in the maximum of radiation pattern and decreases with a shift from it according to its characteristic. The shift, which defines the decrease of the gain, is an error of the elevation.

The losses caused by a targeting error are calculated by the formula:

$$L_{point} = 12 \cdot (APE/\ BW)^2\ (dB), \tag{15}$$

where APE is the error of the elevation, degrees; BW is the width of the antenna gain by the level 3 dB, degrees.

### 3.3. Polarizing losses

Polarizing losses arise due to the fact that the polarization of a coming wave differs from the polarization of the receiving antenna. At consideration of polarizing losses, one should consider Faraday's effect, i.e., rotation of the plane of polarization of the wave when passing through the ionosphere. At the frequencies over 2 GHz, the influence of the effect is insignificant.

Polarizing losses are calculated by the formula [3]:

$$L_{pol} = -10\log_{10}\left(\frac{1}{2}\left[1+\frac{4e_{trans}\cdot e_{rec}}{(1+e_{trans}^2)(1+e_{rec}^2)} + \frac{(1-e_{trans}^2)(1-e_{rec}^2)\cos(2\cdot \mathrm{pol})}{(1+e_{trans}^2)(1+e_{rec}^2)}\right]\right)\ (dB), \tag{16}$$

where $e_{trans}$, $e_{rec}$ is the coefficient of ellipticity of polarization of the transmitting and receiving antennas (the ratio of a small half shaft of an ellipse to the big one); pol is the type of polarization, degrees.

### 3.4. Weakening in the atmosphere

At distribution of radio waves in the Earth atmosphere, there is weakening of field tension of due to absorption in gases, dispersion and absorption in hydrometeors (rain, hail, snow, fog, and clouds) and also due to absorption in ionized areas. The main absorption of radio waves generates oxygen and water vapor.

At consideration of the influence of the troposphere on distribution of radio waves, it is necessary to take into account major factors: refraction of radio waves, reradiation by troposphere hydrometeors, weakening by gases and hydrometeors, and depolarization.

It is also necessary to consider such phenomenon as absorption in the ionosphere. It is caused by collisions of free charged particles with neutral molecules and atoms. In a process of such collisions, the energy that charged particles receive due to origination of an ordered speed at the influence of the electromagnetic field is transferred to neutral molecules and atoms, i.e., thermal losses take place. The absorption in the ionosphere significantly decreases at the increase in the frequency f (in inverse proportion to a frequency square) because of lag effect of charged particles and, hence, the smaller energy which is taken away from the influencing field. It becomes negligibly small at the frequencies over 100–150 MHz, i.e., it can be not considered in those ranges of frequencies which are applied in modern communication and broadcasting systems using spacecraft.

All listed phenomena are dependent on frequency, geographical location, and elevation. The dependence of the phenomena arising in the atmosphere on frequency is given in Table 1. The type of weakening is presented in the left column; the right column gives the dependence of this phenomenon on various factors of the influence.

The general total weakening of radio signals in the atmosphere is calculated by the formula [4]:

$$At = A_g + \sqrt{(A_r + A_\mathrm{c})^2 + A_s{}^2}\ \text{(dB)}. \qquad (17)$$

### 3.4.1. Weakening in clouds

The value of weakening due to the influence of a clouded sky on inclined routes is calculated by the formula [5]:

$$A_c = (L \cdot K_l) / \sin(\theta)\ \text{(dB)}, \qquad (18)$$

where в is the elevation; L is the statistics of a general column volume of water over Russia is taken from P.840-5; Kl is the coefficient of running weakening, a detailed calculation of which is given in [5].

Table 1. Weakening phenomena in the atmosphere

| Type of weakening | Influencing factor |
|---|---|
| Weakening due to overcast $A_c$, dB [5] | At the frequencies below 10 GHz, this factor can usually be neglected. At the frequencies over 10 GHz while their increase, weakening becomes a more and more important factor, especially for small elevations |
| Absorption, dispersion and depolarization due to hydrometeors (water drops and ice particles in rainfall) $A_r$, dB [4,6] | These phenomena are especially noticeable at the frequencies over 10 GHz |
| Weakening of radio waves in atmospheric gases on inclined routes $A_g$, dB [7] | The frequency range is 1–1000 GHz |
| Weakening due to tropospheric twinkling $A_s$, dB [4,8,9] | At low elevations (10°) and at the frequencies about more than 10 GHz, tropospheric blinking can sometimes cause serious deterioration in performance data. At very small elevations (4° for the routes passing over the land, and 5° for the routes passing over water or along the coast), fading caused by multibeam distribution can be especially strong. In some places ionospheric blinking can play an important role at the frequencies lower about 6 GHz |

### 3.4.2. Weakening in rain

Weakening of a signal in hydrometeors is caused, first, by dispersion of an electromagnetic energy by particles. Under the influence of an influencing field, each particle becomes a secondary radiator disseminating an electromagnetic energy in various directions, and, as a result, the energy share decreases, which distributing to a reception point. The second reason of weakening of field intensity in hydrometeors is nonresonance absorption in particles, which also depends on their quantity, electric properties, and frequency. This phenomenon depends on frequency, elevation, and intensity of rainfall.

The influence of rain is calculated by the formula [4]:

$$A_r = A_{0.01} \times$$
$$\times\, (p/0.01)^{-(0.655+0.033\,\mathrm{In}(p)) - 0.045\,\mathrm{In}(A_{0.01}) - \beta(1-p)\sin\theta}\ \text{(dB)}, \quad (19)$$

where $A_{0.01}$ is the predicted weakening value, dB; $p$ is the percent of the time of an average year, %.

The percent of the time of an average year at which the calculation of losses in the atmosphere is carried out, for example 0.01%, means that during 99.99% of time of a year weakening on the radio line will not exceed the calculated value and availability of the radio line will be 99.99%.

The predicted value of weakening $A_{0.01}$ being exceeded during 0.01% of the time of the average time is found by the formula:

$$A_{0.01} = \gamma_r \cdot L_e\ \text{(dB)}, \quad (20)$$

where $L_e$ is the effective route length, km; $\gamma_r$ is the running weakening, a detailed calculation of which is given in [4], dB/km.

An effective route length is calculated by the formula:

$$L_e = L_r \cdot v_{0.01}\ \text{(km)}, \quad (21)$$

where $L_r$ is the elevation view of the length of the inclined route, km; $v_{0.01}$ is the coefficient of fine tuning in vertical direction for 0.01% of time.

A detailed calculation of the coefficient of fine tuning in vertical direction, $v_{0.01}$ for 0.01% of time, the coefficient of weakening in horizontal direction and other parameters are given in [4].

If the height of the station above sea level is higher than the rain layer height, then the predicted weakening for any percent of time is equal to zero and further calculations are not required. The calculation of the height of the layer of rain is given in [10].

An assessment of the weakening exceeded for other percent of the time of an average year in the range from 0.001% to 5% is defined by recalculation on the value of weakening of 0.01% of the time of an average year.

### 3.4.3. Weakening in atmospheric gases

Weakening of a signal is caused by the absorption phenomenon in atmospheric gases and depends on the frequency, elevation, altitude above sea level, and density of water vapor.

Weakening on the route for communication systems can be calculated by division of the atmosphere into the horizontal layers defining a profile of the change of such parameters as pressure, temperature, and humidity along the route.

Full losses in atmospheric gases are calculated by the formula [7]:

$$A_g = \sum_{n=1}^{k} a_n \gamma_r\ \text{(dB)}, \quad (22)$$

where $a_n$ is the length of a part of the route in the layer, km.

A running attenuation $\gamma_r$ is calculated by summing spectral lines by the formula:

$$\gamma_r = 0.1820 f_{\text{down}} (N''_{oh}(f_{\text{down}}) +$$
$$+ N''_{\text{wat. vap}}(f_{\text{down}}))\ \text{(dB/km)}, \quad (23)$$

where $(N''_{oh}(f_{\text{down}}), N''_{\text{wat. vap}}(f_{\text{down}})$ is the imaginary part of the frequency dependent complex reflective capability, the calculation of which is given in [7].

To calculate the general attenuation on the satellite line it is necessary to know not only a running attenuation in each point of the line, but also the length of the route on which there is a running attenuation of such value. To determine this length, it is necessary to consider a curvature of the beam spreading above the Earth.

### 3.4.4. Weakening because of tropospheric blinkings

The value of tropospheric blinkings depends on the value and structure of changes of the index of a refraction, increasing with the increase of the frequency and length of the route passing through the distribution environment and decreasing in process of narrowing of the antenna radiation pattern due to averaging of its aperture.

The depth of fading is calculated by the following formula [4]:

$$A_s = a(p) \cdot \sigma \text{ (dB)}, \quad (24)$$

where σ is the standard deviation of a signal for the considered period and the route of propagation, dB; *a(p)* is the time percent coefficient for the considered *p*.

A detailed calculation of the components, comprising the formula (24), is presented in [4,8,9].

## 3.5. Results of calculation

Basic data and results of calculation can be presented in the table form, the template of which is given below (Table 2).

Table 2

| Parameter | Necessarily / Desirably for calculation |
|---|---|
| Information speed of data transmission, Mbp/s | Necessarily |
| Frequency band, MHz | Desirably |
| Required ratio $E_b/N0_{\text{required}}$, dB | Necessarily |
| Frequency, GHz | Necessarily |
| **EIRP of the transmitter, dBW**<br>Gain of the transmitting antenna, dB<br>Losses in a microwave path, dB<br>Power of the transmitter, W | Necessarily<br>Desirably<br>Desirably<br>Desirably |
| **Losses of pointing of a transmitting antenna, dB**<br>Width of the gain of the transmitting antenna, degrees<br>Error of a pointing angle, degrees | Necessarily<br>Desirably<br>Desirably |
| **Losses in a free space, dB**<br>Range of communication, km<br>Elevation, degrees<br>Reception altitude above the sea level, km<br>Reception width, degrees<br>Coefficient of percent of time, %<br>Intensity of rainfall, km | Necessarily<br>Desirably<br>Necessarily<br>Necessarily<br>Necessarily<br>Necessarily<br>Necessarily |
| **Losses in the atmosphere, dB**<br>Weakening in the rain, dB<br>Weakening in atmospheric gases, dB<br>Weakening in clouds, dB<br>Weakening because of blinkings, dB<br>Diameter of the receiving antenna, m<br>Efficiency of using of the receiving antenna | Necessarily<br>Necessarily<br>Necessarily<br>Necessarily<br>Necessarily<br>Necessarily<br>Necessarily |
| **Losses of pointing of the receiving antenna, dB**<br>Width of the gain of the receiving antenna, degrees<br>Error of a pointing angle, degrees | Necessarily<br>Desirably<br>Desirably |
| **Losses on the blister of the receiving antenna, dB** | Necessarily |
| **Q-factor (G/T)**<br>Gain of the receiving antenna, dB<br>Noise temperature of the system, K<br>Losses in a microwave path, dB | Necessarily<br>Desirably<br>Desirably<br>Desirably |
| **Stock, dB** | Necessarily |

## Conclusion

The article presents the method of calculation of an energy margin in the radio link a point-to-point (“spacecraft– station”). All factors, influencing the value of an energy margin in the radio link are listed. It is shown from what components the value of losses in the atmosphere of Earth is produced. Analytical expressions for carrying out the corresponding calculations are given. References to ITU are provided. Formulae of calculation of an equivalent noise temperature of the receiver are also given. Thus, gaps in calculations arising due to incomplete record of the components are eliminated. These gaps can cause overestimations of the results and further corrections.

The technique will be useful to the experts who are engaged in calculations of radio lines, and its use at the enterprises of a space-rocket industry will allow one to correlate easily the calculations and to carry out expert estimates by uniform rules.

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