Investigation of the influence of the location on the rate of Sub THz space communications channels

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The need to increase a rate of long-distance space links, in particular, supposed to be developed for communication with the Martian and longer space missions, as well as the space observatory Millimetron, leads to the development of a subterahertz frequency band for this purpose [1]. However, it is known that the terahertz waveband has a noticeable level of absorption in the atmosphere, which appreciably reduces the effect of increasing the channel capacity due to the expansion of the transmission band and the working frequency. Now the main long-distance space communication stations in Russia working in the centimeter range are located in Ussuriysk, Evpatoria, Kalyazin and Bear Lake, while the altitude above the sea level is very small and the absorption of mm and sub-mm waves is significant. Astronomical observations on sub THz waves are usually carried out in high-altitude conditions (over 2500 m), which significantly reduces the effect of the atmosphere on the propagation of these waves. The purpose of this work was to investigate the dependence of the capacity of long-range space communication channels on sub-THz waves from the location of the ground-based communication antenna. To compare the existing sites used for space communications now and prospective ones located in the mountains. Our purpose is to estimate a THz-data link with the best cooled receiver in the "Earth-Space" configuration.

The main parameter influencing the estimation is the data link availability in a specific region and amount of transmitted-received information throughout a year. The location of some stations is shown in Table 1.

Table 1

Object name	Geographic coordinates	Altitude above sea level, m
Suffa Radio Observatory on the Suffa plateau, Uzbekistan.	39°37′N 68°27′E	2335
East Center for Deep Space Communications, Galenki (Ussuriysk), Russia.	44°00′58″N 131°45′25″E	93
Center for Distant Space Communication (Yevpatoria, Crimea)	45°11'20.7"N 33°11'14.5"E	15

When calculating the capacity of the channel, they relied on the method described in [2] with the only difference that the attenuation of the atmosphere decreased with altitude.

At the initial stage, the program reads from the file the altitude profiles of pressure, temperature and humidity obtained by meteorological observations. These data are available at all major weather stations and are posted on the Internet two or four times a day [3]. Tabular data from the file is subjected to piecewise linear interpolation, are given in mutual correspondence of dimensions, and the measurement limits are limited by the altitude of the weather station above sea level h_min and the altitude of the probe h_max (usually 20-30km). The main stage of the program is integration of attenuation coefficients in oxygen and water vapor in height at a given frequency:

$$\tau_{oxygen}(f) = \int_{h\_min}^{h\_max} A_{oxygen}(f, P(h), W(h), T(h))dh$$

$$\tau_{water}(f) = \int_{h\_min}^{h\_max} A_{water}(f, P(h), W(h), T(h))dh$$

where: τ_{oxygen} integral attenuation in oxygen at the zenith, Np τ_{water} – integral attenuation in water vapor at the zenith, Np *h_min u h_max* – range of probe height, km A_{oxygen} – stationary absorption in oxygen, Np/km A_{water} – absorption in stationary conditions in water vapor, Np/km *f* – frequency, GHz *P(h)* – altitude pressure profile, mbar *W(h)* – altitude humidity profile, g/m^3 *T(h)* – altitude profile of temperature, K *h* – height, km.

The result is a spectrum of integral attenuation in the atmosphere. Substituting the center frequencies, the integral weakening of the corresponding transparency windows is calculated. The functions *Aoxygen* (f, P, W, T) and *Awater* (f, P, W, T) are internal functions of the MPM Liebe basic program and determine the linear absorption (He / km) under steady-state conditions, i.e. on a horizontal track. By integrating them with the corresponding profiles, we obtain an integral attenuation on the vertical path (He). The total absorption is the arithmetic sum of the absorptions in oxygen and in water vapor, and the conversion of the quantities in neperes into decibels is carried out by multiplying by a constant of 8.68.

Changing the height h_min in the integrals, we calculate the integral attenuation from the corresponding height, i.e. if the ground station were located at an altitude h_min taking into account the current atmospheric profile.

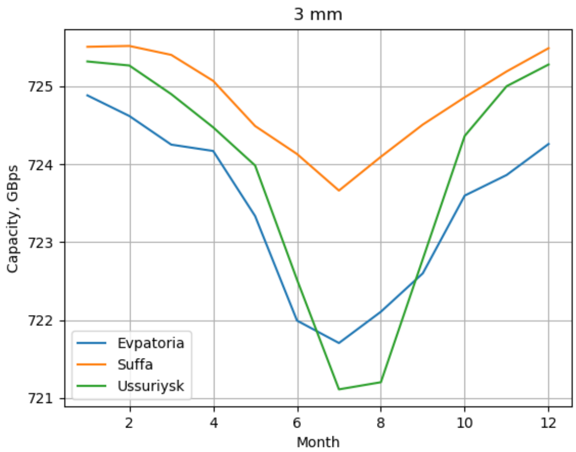

Fig. 1. Estimated THz-link budget for 3mm wave length during a year with cryogenically cooled receiver

Figure 1 showing the variation of the channel capacity for 3mm wavelengths. The calculation was carried out for the following parameters: the width of the window-band is 50GHz, the physical temperature of the receiver is 4K, the equivalent receiver noise temperature is 100K [4], the direction of transmission is zenith.

The total amount of information available for transmission for the year will be: Evpatoria $22502*10^{15}$bytes, Ussuriysk $22514.670*10^{15}$bytes, Suffa 22545 10^{15}bytes. Expectedly there is a failure in the summer months due to increased humidity, but it is not dramatic in comparison to the three locations. In the annual cycle, the difference is also less than 1%. Certainly when the space port of the channel is located far from the zenith affect of the atmosphere increase. For shorter SubTHz atmospheric windows of transparency (2, 1.3 and 0.8 mm) too. The work was supported by the IAP RAS state program (project No. 0035-2014-0021)

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