Atmospheric Propagation Of SubTHz Waves And Space, 6G & 7G Communications

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Abstract. The work is devoted to the actual problem of data rate of wireless telecommunication channels. Presented analysis of the telecommunication channel subterahertz (subTHz) frequency range - as the most promising band for the implementation of wireless telecommunications for space links and terrestrial cellular communications of high capacity. A channel considered as a combination of high effective transponder / transmitter duplex together with an open high dissipative atmospheric line. The means to achieve a high signal / noise ratio is usage of low-noise cryogenic receivers. The theoretical analysis of data rates for various atmospheric conditions and technical implementations of communication channels demonstrated reasonable limits of cooling of receivers, providing a weighty increase channel capacity, while deeper cooling is impractical due to weather restrictions in certain ranges and conditions of signal propagation, including altitude and seasonal features.

INTRODUCTION

Multimedia and data channels are like yin and yang. Multimedia pushes to increase the capacity of the data channel, and new high-speed data channels encourage the media industry to create new products that use new capacities. 5G network is already in the process of launching. The 6G standard is being formed and it considers the frequencies of 230 GHz, 340 GHz \cite{1}. The use of a frequency of 700 GHz is considered in \cite{2} for 7G, however, in this range atmospheric attenuation is too high and possibilities of use will be greatly limited. ~ 700 GHz frequencies definitely can be used as an alternative to Wi-Fi, operating at 2.4 GHz and 5 GHz. Whereas 230 GHz, 340 GHz can be used for outdoor communications, including in crowded places, and access points with frequencies of 230, 340 need to be placement not so close as for 700 GHz due differ atmospheric attenuation.

When the use of these frequencies in mobile phones is discussed, should not be forgotten not only the atmosphere and limitations connected with medical standards too.

An additional way to increase the capacity of communication channels is to reduce the noise of the receiver, and here we should discuss a problem of adequate cryogenic cooling systems. At the moment, there are no miniature cooling systems for use in mobile devices, and those that are relatively small (Peltier cooler) require essential power sources. However, it is not necessary to use cooling on mobile devices itself. Signal transmission from the base station to the mobile device is achieved by increasing the source power at the base station. Using a high power signal source in a mobile device is also not necessary - it is possible to install a cooled receiver at the base station to increase sensitivity \cite{3}. But in connection with the described features, the use of the sub-THz frequency range for organizing Earth-Space communications is preferably.
CAPACITY ESTIMATION OF THZ DATA CHANNEL

The Earth-Earth ground channel, which is of particular interest [4] for mass cellular telecommunications, can be estimated using the calculation method [5] for a fixed value of atmospheric absorption, which depends on the elevation and ambient temperature. For a subTHz data channel, a heterodyne [6] circuit should be used. The altitude above the sea level of the place is chosen small with a significant absorption of THz waves, but this is typical for places of mass residence of people and the need for high-performance communication. In the case of the Earth-Space channel, the atmospheric absorption value changes with increasing altitude, which required changes in the calculation method, namely, to calculate the integral atmospheric absorption value from the altitude of the ground part of the channel to the altitude at which the space part of the channel is located. And here the task has a noticeable practical sense, since space communications are carried out both from instruments located relatively low above sea level (long-distance space communication systems in the cities of Yevpatoriya, Kalyazin, the settlement of Medvezhye Lakes), and in the mountains. Obviously, the latter for the implementation of communications in the subTHz and especially in the THz bands are much more promising.

An important parameter in the "Earth - the Earth’s orbit" channel is the angle of the satellite’s position above the horizon since the satellite moves through the sky (research satellites) and tracking is necessary, or they are located in a geostationary orbit (communication satellites).

![Graph showing capacity vs. zenith angle for two seasons, 338 GHz](image)

FIGURE 1. Capacity when changing the zenith angle for two seasons, 338 GHz. (0º-upright, 90º-horizontal)

The methodology is based on the MPM Liebe [7] atmospheric radio transparency calculation program, which allows one to calculate the absorption spectrum in the atmosphere under given stationary conditions - pressure, temperature, and humidity. Integral attenuation in oxygen and in water vapor at the zenith are calculated by (1).

\[
\tau_{\text{oxygen}}(f) = \int_{h_{\text{min}}}^{h_{\text{max}}} A_{\text{oxygen}}(f, P(h), W(h), T(h))\,dh
\]

(1)

\[
\tau_{\text{water}}(f) = \int_{h_{\text{min}}}^{h_{\text{max}}} A_{\text{water}}(f, P(h), W(h), T(h))\,dh
\]

Integral attenuation on the track with a given zenith angle are obtained from (2). For communication channels with objects located in the Earth’s orbit, their support in the sky already has a significant effect, and depending on their
own rotation, sometimes very fast. Even at an angle of \( \sim 70^\circ \), the optical thickness will be two atmospheres - which means a significant increase in the integral attenuation for the earth-space channel. Therefore, the influence of the slope of the transmission line relative to the vertical on the transparency window capacity is analyzed below. In winter, a small effect is expected, in the summer at an altitude of 2 km at an angle of \( \sim 70^\circ \), the window capacity drops to \( \sim 0.09 \) Mb/s, while in winter under the same conditions the capacity increases by 3 orders of magnitude (FIGURE 1).

\[
\tau_0(f) = \tau(f) \cdot \sec(\theta)
\]  

(2)

The estimates were made for a low-noise cryogenic SIS receiver with \( T = 4K \) and with a noise temperature of \( \sim 50K \), and as an uncooled alternative, a Schottky Barrier Semiconductor Diode receiver at room temperature with a noise temperature of 2700K. The calculation was carried out for an altitude of 4 km, the receiver is directed vertically upward (angle 0 \(^\circ\)).

**CONCLUSION**

The use of earth-space channels for data transmission with satellite constellation in orbit of the earth or long-range space missions is promising, it is also possible to use the THz earth-space and space-space channels in the three-link model “ground station” - “orbital station” - “interplanetary missions”. Also using receiver cooling can increase data link capacity. Extremely high sensitivity (low noises) of receivers are related to using superconductivity, which uses at this moment cryogenic cooling. Projects Starlink or OneWeb (so-called “global Wi-Fi”) are developing in such approach. Its propose to use base station to provide regular Wi-Fi or 4G data channel. On such base station receiver cooling (cryo cooling) can be use. At this moment we are not talking about of using cooling systems in mobile terminals because of its "not mobility". But in the future some systems can be developed, or due to advances in electronics noises of subTHz receivers will be reduced The study of the atmospheric absorption in the SubTHz range in the sense of the inhomogeneity of its transmission in the frequency and location is the separate and very popular task. It includes forming an agenda for developers of THz wave equipment. The tasks of creating highly efficient wireless communications closely related to the problems of implementing long-range space missions.

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