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The Research Program of Millimetric Radio Waves Attenuation Characteristics on Perspective Communication Lines of Ukraine

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Abstract - **The purpose of the project is determination of typical for Ukraine full values of vertical and the specific horizontal atmospheric attenuation for EHF band radio waves, their cumulative functions, as well as the statistical parameters of its variations over the different regions of Ukraine taking into account the factors of seasonal and weather variability. The lack of information on this issue negatively affects for future communication systems development and optimization.**

Keywords - **atmospheric attenuation, millimetric band, radio relay and space-ground communication, TCSET 2016.**

I. Description of the Problem and the Issue Status

Perspectivity of large-scale use of a EHF band in radio-relay and space-ground communications tasks is caused by new capabilities of wireless communications of significantly high transmission rate (to 10 Gbps) in comparison with the conventional communication channels disposed in more low frequency band. The physical basis of such revolutionary capacity growth of telecommunication systems is that, for example, only E-band (the sub bands allocated for communications: 71-76, 81-85, 92-95 GHz) exceed a spectrum a total spectrum of all traditionally used for these purposes microwave sub bands.

In this regard, in the last 10 years the world has the accelerated escalating of the efforts both addressing on hardware solutions providing telecommunications tasks as well as for research of the radio propagation in EHF band in vertical and horizontal directions considering microclimatic and seasonally-weather features of various regions of the world. Moreover, the instrumental part of the problem can be solved to a large extent based on existing technological developments in the element base EHF band of the most developed countries. This is illustrated by millimetric band communication systems, which are produced for commercial purposes by well-known companies like ADC Communications, Samsung, LG Electronics, Matsushita Electric (Panasonic), Philips, Intel, Ericsson and others ..

The decision of the second part of the problem needs an individual consideration of the propagation of radio waves microwave band considering the territorial, season and weather variability.

This is primarily related to the significantly increased influence of meteorological parameters on the characteristics of the signals microwave band on surface and vertical lines.

Moreover, if countries such as the UK, Czech Republic, Hungary, Germany, USA, Japan, the European part of Russia, these issues a great extent explored thanks to the carrying out of long-term experimental and theoretical research in the rest of the world, these research areas are either in primary phase, or not carried out at all.

Relevance of these studies to provide information about depth and frequency of fading in signal microwave band for surface lines and for sloping lines of communication is in addition to scientific, primarily economic importance. The knowledge and the adequate prediction of these characteristics allows to estimate reliably of created radio links, choose the optimum size of the aperture, the output power and receiver sensitivity, routes and others, the technical requirements necessary for economic provision a predetermined uninterrupted level for information transmitted in communication systems of new generation.

The special importance of these tasks is related to the expected in wide-area applying of microwave band telecommunication systems throughout the world. The transition to the design and construction of such systems in the US and the EU can already be described as a new wave of innovation that is comparable with the advent of cellular standards and Wi-Fi [1].

It is appropriate to note that for justified and rational choice of hardware ensuring of such systems, or for their design and production in Ukraine at the moment there are obstructions. For the territory of Ukraine is characterized by the absence of direct experimental information on monthly averages of atmospheric attenuation and statistical distributions of instantaneous values. So, there are no original researches attenuation of radio waves microwave band and, thus, remain open questions about the applicability of the results of

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Russian, European or American authors to the territory of Ukraine as a whole, and especially to its particular regions. There is no meteorological information on the water content of the cloud layer, and its variability from region to region, as well as data on rainfall intensities obtained with high temporal resolution (less than a minute). Also requires a physical explanation and clarification of anomalous nature of radio-physical characteristics in the attenuation and fading of millimeter radio waves on the surface and sloping tracks. The possibility to use of the available meteorological data on the distribution of the different types of clouds in combination with the characteristic values of their water content, or similar data on the intensity of the rains to solve this imperative problems of radiophysics is not obvious and needs to research.

II. Purpose and Prerequisites Necessary for the Implementation of the Project in Ukraine.

Increasing interest in the use of microwave radio relay and ground space communication caused the observed doubling every 1-2 years information streams.

According to our estimations [2-4], in all transparency windows of microwave band, average values, for example, a complete vertical attenuation for typical meteorological situations in middle and high latitudes does not exceed 10 - 15 dB. Moreover, such values are typical for both clear and cloudy atmosphere, and in the rain (Fig. 1-2). In the millimetric band, for example, up to 100 GHz, the average attenuation, as a rule, do not exceed values of 3 - 5 dB [4]. These values can be considered acceptable for most of telecommunication applications.

It is worth noting that the analysis of average attenuation values in atmosphere at a given operating frequency allows you to make useful conclusions about the territorial, seasonal, weather, microclimate variability of the signal passing. However, more important in telecommunication applications is knowledge of attenuation statistics in horizontal, vertical and sloping paths measured (estimated) for the one-year period of observation, but with a small (from fractions to several minutes) intervals averaging. The importance of this question related to the fact that the design, and then for the certification of communication link must be adequately predict its reliability and the continuous operation. The requirements for this parameter are very strict, because the allowable value of the loss operation in data transmission must not more than few to tens of minutes for a one-year work period.

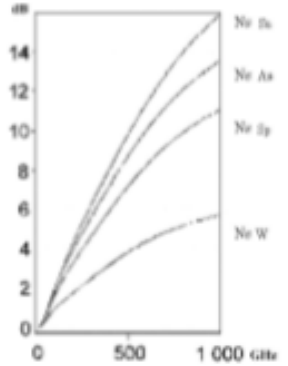
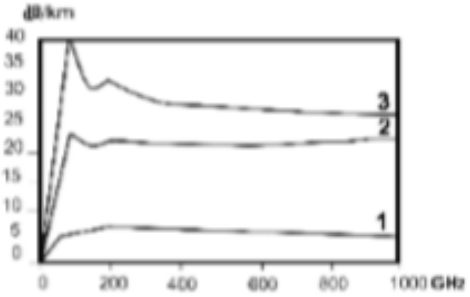


Fig. 1. Frequency dependence of the averaged values of vertical attenuation of radio waves for Nimbostratus (Ns) type clouds over Ukraine;
Su - summer, A - autumn, W - Winter, Sp - Spring



1 - 10 mm/h, 2 - 50 mm/h, 3 - 100 mm/h

Fig. 2. Frequency dependence of specific attenuation (γ) for the different rain intensities

In this regard, the last 10 - 15 years in the world become more active research of microclimatic characteristics of atmospheric radio wave attenuation of millimetric band specific to different countries.

Additional impetus to these radiophysical studies gave important decisions of the United States Federal Communications Commission and respective Commission in the EU adopted in 2005 and 2006, which regulate usage of millimetric band in these vast regions of the world, as well as periodically updated recommendations of ITU, which are focused on providing approximate estimates of parameters model radio propagation. It should be noted that by recommending estimation models, ITU primarily insists on the direct experimental accumulation of millimetric band radio physical data in each country [5]. This is related to the fact that the attenuation in millimetric band particularly sensitive to microclimatic characteristics a particular area that causes the differences (often substantial) of attenuation in the communication channels especially in cloudy and rainy weather.

For example, even located in the middle latitudes of the territories of Ukraine and many EU countries it can be assumed that there are regional characteristics [5], which require consideration when designing

communication links in millimetric band. Lack of attention to these issues through the experimental data accumulation will often lead either to unnecessary economic losses due to reinsurance in the design (the use of excessive size of the aperture, sensitivity of the receiver, transmitter power) or conversely, to a lack of reliability operated communication links and networks. As an example, solutions to the problem of obtaining these data gaps for the tasks of design and operation millimetric band communication networks in the world, is possible show research of Czech, English, Italian and others colleagues [6-10 and others].

Given in [4] the probability of observing the averaged values of vertical attenuation Sc, Ac Ns types of clouds and demonstrate the existence of significant regional and seasonal differences in this parameter, and for Ukraine. Even more significant regional differences are observed when comparing the histograms of probability values of rain attenuation (Figure 3) constructed on the basis of meteorological data with low temporal resolution [4].

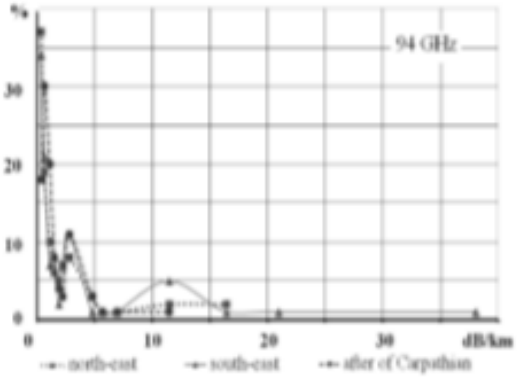


Fig. 3. Example of probability distribution (% of the total time of the event of rain) for the values of specific attenuation of rain in August in various regions of Ukraine

Existence of differences in theoretical estimated values at times, can be regarded as an indirect indication of the presence of significant differences in the cumulative function of the atmospheric attenuation in the cloud and rain layer obtained with high temporal resolution. These factors also point to the need for and urgency of the implementation of Ukraine, described here the research program. The main objective of this project is exactly be composed in a definition for Ukraine's cumulative functions of full vertical and specific horizontal atmospheric attenuation of millimeter band radio waves as well as the statistical parameters of its variations over the different regions considering seasonal and weather variability factors.

III. The Methodology and Tasks of the Developed Research Program

In accordance with the recommendations of the ITU [5], in each country should be held the data collection of excessive durations of attenuation caused by weather events with time resolution of a few to tens of seconds. This information matching the parameters of typical climatic conditions of each region, requires the development of communication networks and communication lines equipment. For Ukraine, these data are not available.

The main idea of this research program is:

- experimental studies of statistic data atmospheric attenuations in one of the regions of Ukraine (Kharkiv) at various points millimetric band; - estimation the accuracy of the following model description of these parameters from the available many years of meteorological data; and the transfer of the design approach to the whole territory of Ukraine and on the different sub-bands millimetric waves.

In the experimental part of the discussion project data about the cumulative distribution function of signals reducing and fading and parameters necessary for the design of microwave communication lines, will be obtained through a year-round observations at three points millimetric band (37 GHz, 60 GHz and 93 GHz) on horizontal tracks. Necessary for the design of terrestrial line space communication information about similar parameters will be obtained by treatment and recovery results of radiometric sensing of the atmosphere in the vertical direction at 39 GHz and 94 GHz. Data observed in millimetric band about abnormal or excessive atmospheric attenuation events will be accompanied by contact and remote measurements accompanying physical parameters and processes in the atmosphere. To solve these problems will be used lidar techniques and fire monitoring atmospheric parameters such as its temperature inhomogeneities, the height of the cloud cover and altitude distributions of aerosols, as well as special high-speed devices for contact measurements of intensity of precipitation, droplet size distribution, and standard meteorological parameters. These related information are important for understanding the nature and subsequent modeling and forecasting of the attenuation.

To carry out of theoretical research this issue will be used by the methods of mathematical propagation modeling millimetric and submillimeter radio waves in a clear atmosphere, cloud environment and rain. Required for these calculations meteorological information will be obtained by attracting the most statistically affluent databases [11, etc.], ITU recommended models [5, etc.] and by comparing the model results with the results of our experiments. Special attention will be paid to the physical explanation and model description super strong and anomalous values and processes in atmospheric attenuation. First of all it refers to the events of mismatch to generally accepted theoretical concepts of high atmospheric attenuation values in a clear atmosphere and clouds in millimetric band, as well as in rain in submillimetric band [12]. It is also research of possibilities to improve the reliability of communication

lines by integrating optical and millimetric band channels.

To solve outlined above problems in the work plans to provide the following tasks:

- upgrade of the transmitting and radiometric measurement systems of 37 GHz, 60 GHz, 94 GHz bands, and to hold a series of annual observations of atmospheric attenuation in various synoptic situations;
- experimentally and theoretically investigate the nature and mechanisms of abnormal manifestations in the propagation of millimetric band signals in terms of clear and cloudy atmosphere;
- select meteorological and radio physical models to ensure the adequacy calculations of atmospheric attenuation at different points in the MM range;
- to carry out calculations and their comparison with the experimentally derived data on the characteristics of a full vertical and horizontal attenuation of radio waves per unit length MM range, taking into account seasonal and regional characteristics of condition the atmosphere in the Ukraine;
- perform a statistical assessment of atmospheric attenuation on the territory of Ukraine, with respect to its analysis of seasonal, weather, frequency, territorial, microclimatic variability;
- outline the prospects for additional research of the current actual scientific field, including by integrating with the organizations of the countries of Eastern Europe and the EU;
- upgrade the lidar complex of KNURE to expand the dynamic range of the received signal and to reduce the minimum height sensingand hold cycles lidar measurements of atmospheric aerosol and atmospheric rain attenuation;
- to hold a series of acoustic sensing of the atmosphere in its different thermodynamic states, and explore the possibility of describing the scattering of electromagnetic millimeter waves in a boundary layer of the atmosphere on the basis of a joint analysis;
- carry out pilot studies of attenuation and interference immunity of local communications channels in the ISM band (60GHz), in relation to tasks of development local (Wi-Fi) and urban communication systems (WiMAX).

The obtained results will allow to fix the main negative environmental factors affecting the signal of millimeter-wave space-ground and radio relay systems, to identify and estimate their impact on the propagation characteristics for different regions of the territory of Ukraine, to ensure the transfer of the received data and regularities in relation to the higher frequency waveband including submillimetric band [4, 13].

IV. Equipment complex and participants

In the study of this problem it is expected to use a comprehensive approach involving both theoretical methods for research of atmospheric attenuation in different atmospheric transparency windows, and experimental methods for remote monitoring of atmospheric parameters using the transceiver and radiometric equipment millimetric band, lidar equipment and acoustic sensing of the atmosphere.

On the basis of in KHNURE, IRE NASU and HAI hardware backlog in the experimental part of the research will be used:

- Two horizontal measuring path (length 600 m) with the transceiver equipment for bands 93 GHz and 37 GHz in combination with fast disdromer (measure of the droplet size distribution) and a set of standard meteorological equipment (IRE NASU) as well as horizontal measuring path (up to 100m) a transceiver equipment 60 GHz [14-15] (KNURE, dep. RTICS).

Designed for continuous monitoring of the dynamics of changes in the values of atmospheric attenuation per unit length in conjunction with the accompanying measurements of meteorological parameters of the atmosphere and physical parameters of precipitation;

- 3 mm band radiometer [16] (HAI, dep. PRESLA) and 8 mm band radiometer (KNURE, dep. RTICS).

Designed for continuous remote monitoring the dynamics of change the values of complete vertical atmospheric attenuation, including the presence of clouds and other hydrometeor components;

- Portable handheld sodar (KNURE, NCA).

Designed for continuous remote monitoring of thermodynamic processes in the atmosphere, including the dynamics of change in the temperature profile and its turbulent fluctuations [17];

- Lidar of near-infrared band (KNURE, dep. RTICS).

Intended for remote monitoring of high-altitude distributions of the atmosphere aerosol component, height of cloud cover and other parameters attendant to study of abnormal attenuation events in the atmosphere [18];

- measuring stands of millimetric band that provide a solve configuration tasks improved circuit solutions used in the modernization of the receiving and transmitting equipment and radiometric measuring complex.

Taken together, this equipment complex will not only provides a solution to the above experimental part of the research program, but also serve as a basis for the formation of and participation in promising programs of international scientific cooperation to address similar problems of radio wave propagation millimetric and submillimeter bands.

V. Conclusion

The resulting research data, models and technical solutions, as well as an upgraded complex of equipment will represent the scientific and practical interest for Ukrainian and some foreign commercial organizations, which in the long term plan to participate in the licensing implementation in Ukraine of radio relay and satellite communication systems in millimetric band.

Employing of planned results will contribute to building on the territory of Ukraine, as part of a pan-European telecommunication space, in form modern high-speed networks based on European standards. The results of research related to the study of influence of atmospheric parameters in different seasons and weather conditions on the propagation characteristics of signals of millimetric band will also be useful for remote sensing tasks and fundamental research environment.

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