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The Project of Joint Investigations of Millimetre Waves Propagations for Ukrainian Advanced 5G Communication Lines

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Abstract—The purpose of the project is determination of the specific horizontal and full vertical atmospheric attenuation for millimeter 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 5G communication systems development.

Keywords — *atmospheric attenuation, millimetre band, radio relay and space-ground communication,*

I. INTRODUCTION

It is possible to conclude on the basis of numerous prognoses, the capacity of mobile communication networks will have to provide increasing of traffic exceeding in a present volume more than in 1000 times after 2020. For providing of such reliable, super-high carrying capacity an over-dense network must provide the frequency band not below of a few hundred MHz with possibility of expansion up to a few GHz.

The 5G telecommunication format supposes that super-dense networks will work mainly in a range 10-100 GHz, here providing good integration of new technologies of radio-access with the already built level of cellular networks. In basis of such integration it will be complex set of old standards and technologies (MIMO, D2D, UMTS, GSM, LTE OFDMA, Wi - Fi, etc.) as well as development of the new decisions which are related not only to usage of millimeter waves band (MM WB) but also with the use of ground-space communication channels due to the special groups of telecommunication nano-satellites. The volume of data on a narrow-directed channel for such 5G networks will reach from a 1 Gb/s up to 10 Gb/s [1], what will allow to serve more than million devices on a 1 km² already in 2020 on speeds in 100 and more times higher, than maximum speed at a 4G network of modern LTE standards.

Besides, the important role will play accounting of features and particularities of MM waves propagation along

horizontal and sloping traces when the problems of organization of new standards as well as organization of apparatus, technical and other decisions will be solved. The clear knowledge of these questions is very important for reliability, economic and technical optimization of future 5G technologies. It has not only scientific and technical sense but also relate to economic efficiency of accepted technical decisions with their optimization for the different regions of country. In fact some firms and governments from a number of world leaders already expended for development 5G networks from hundreds of millions up to milliards of USD during this technological racing.

It is well known that increasing of used radiofrequencies diminishes a distance of wireless connection headily as well as increases a dependence of propagation parameters on meteorological and micro-climatic situation. All ones essentially influence on the spatial configuration and sizes of a network cells. This circumstance will influence also on the cost of development, exploitation and maintenance of 5G networks as well as on the cost of devices that must be at minimum possible level. In view of this there is an importance to take into account the influence of regional micro-climatic features and particularities of construction and work of communication networks of MM WB.

At a few last years took place the accelerated escalating of the efforts in the world with both directions on hardware solutions providing telecommunications tasks [2-6] as well as for research of the radio propagation in MM WB band in vertical and horizontal directions considering microclimatic and seasonally-weather features of various regions of the world [7-13]. At that, the instrumental part of the problem can be solved on the grounds of modern technological achievements in the MM WB element basis of the most developed countries. It illustrates the MM WB communication systems which produce the well-known companies like ADC Communications, Samsung, LG Electronics, Matsushita Electric (Panasonic), Philips, Intel, Ericsson and others for commercial purposes. The decision of the second part of the problem require of individual

consideration of propagation peculiarities at MM WB on dependence of territorial, season and weather variability.

Moreover, if for countries such as the UK, Czech Republic, Hungary, Germany, USA, Japan, the European part of Russia, these issues had explored at the expense of carrying out of long-term experimental and theoretical research, same researches for the territory of Ukraine not carried out at all. In view of this here absent any direct experimental data about the average monthly values of the atmospheric opacity and statistical distributions of their instantaneous values. The questions of applicability of results of Russian and European researches as it applies to the separate regions of territory of Ukraine remain not investigated. Meteorological information about the water-content of cloudy layer and her changeability from a region to the region of Ukraine is absent. There are no data about intensities of rains got with a small temporal resolution (less than minute). Requires also physical explanation and understanding a nature of anomalous features in a fading and an opacity at MM WB on the near-ground horizontal traces and on the sloping vertical paths.

II. TOPICALITY OF THE PROJECT IN UKRAINE

Actuality of realization of these researches is connected with practical necessity of information about a depth and frequency of signal fading at MM WB for the near-ground horizontal and vertical lines. These data have as scientific, as and economic meaningfulness. In fact knowledge and possibilities of adequate prognostication of these descriptions allow to estimate reliability of the created 5G lines, to optimize the choice of sizes of apertures, the levels of the radiated powers, sensitiveness of receivers, the routes of networks and other technical requirements which are necessary for the economical providing of the necessary level of reliability of transferrable information in communication systems of new generation.

Usage of 5 G radio-lines at MM WB, in spite of increased reaction of these waves on changeability and values of parameters of atmosphere above all are explained by doubling of streams of transferrable information after every 1-2 year. Although, according to our estimations [7-8] in all transparency windows of MM WB the average values of a complete vertical opacity for typical meteorological situations for middle and high latitudes does not exceed 10 - 15 dB as a rul. Moreover, such values are typical for both clear and cloudy atmosphere, and in the rain (Fig. 1-2). At that the average attenuation, as a rule, does not exceed values of 3 - 5 dB [8] for frequencies up to 100 GHz. These values can be considered as 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 to make useful conclusions about comparison estimations of signal propagation on dependence of territorial, seasonal, weather, microclimate variability. However, more important in telecommunication applications is knowledge of attenuation statistics in horizontal, vertical and sloping paths which would measured (estimated) for the one-year period of observation, but with a small (from fractions to several minutes) intervals of averaging. The importance of this

question related to the fact that the design and following certification of communication link must adequately predict its reliability and 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 a few minutes for a one-year work period.

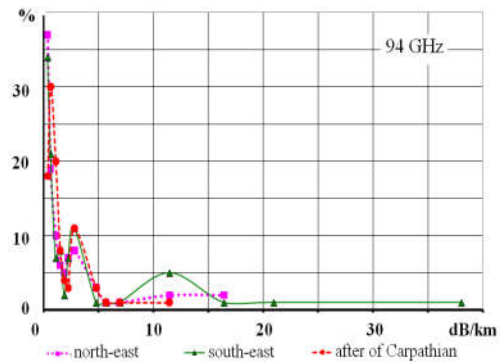


Fig. 1. Example of probability distribution (% of the total time of the event of rain) for the values of specific attenuation of rain in August in various regions of Ukraine.

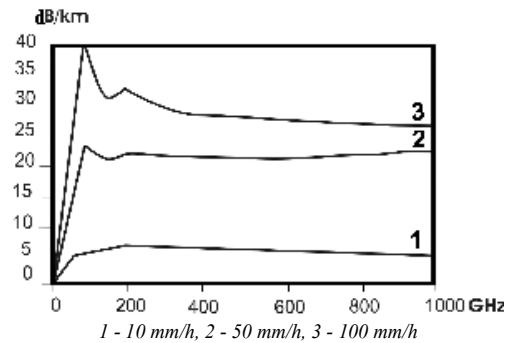


Fig. 2. Frequency dependence of specific attenuation (γ) for the different rain intensities.

Insufficient attention to the decision of these questions by the experimental accumulation of data will often result either in unjustified economic losses due to a reinsurance in planning (application of excessive sizes of apertures or powers of transmitters, non optimal sensitivity of receivers) or, vice versa, to insufficient reliability of the built communication lines and networks.

Exactly on it, recommending some regional evaluation models, ITU insists, first of all, on the necessity of realization of direct experimental accumulation of radio-physical data for MM WB in every concrete country [14]. Indeed, even for the territories of Ukraine or for many EC countries which located in middle latitudes it is possible to suppose the presence of regional features that require an account at planning of MM WB communication lines [8]. As an example ways of decision of problem of receipt of these desiderata of data for the tasks of planning and exploitation of MM WB communication networks in the world it is possible to note the researches [7-13 and other].

On a Fig. 1, as an example, the substantial regional differences of histograms of probabilistic values of

atmospheric opacities are shown for rains at 3 MM WB. However these dependences were constructed by us on the basis of meteorological data only with low temporal resolution [8] for Ukraine.

Presence of multiple distinctions above mentioned theoretical values it is possible show the possibilities of presence of substantial distinctions of cumulative functions of the cloudy opacity and rains opacity also for a high temporal resolution. These circumstances also specify the necessity and actuality of realization of described here program of researches. The main purpose of this project is determination for Ukraine of cumulative functions of the atmospheric opacity at MM WB and also statistical parameters of its variations above different regions taking into account the factors of seasonal and weather changeability.

III. THE METHODOLOGY AND TASKS OF THE DEVELOPED RESEARCH PROGRAM

In accordance with the recommendations of the ITU [14], the data collection of excessive durations of attenuation caused by weather events with time resolution of a few to tens of seconds should be carried out in each country. The development of communication networks and communication lines equipment requires taking into account of the parameters of typical climatic conditions of each region. Today such account is not available for Ukraine in view of absence of necessary data.

The main idea of this research program is:

- experimental studies of statistic data of atmospheric attenuations in one of the regions of Ukraine (Kharkov) at various points of MM WB; - estimation the accuracy of the models which describe these parameters from the available many years meteorological data; - the transfer of the design approach to the whole territory of Ukraine and on the different sub-bands of millimeter waves.

In the experimental part of the discussed project the data about the cumulative function of distribution of atmosphere opacity and its fading as well as about other parameters which are necessary for the design of microwave communication lines will be obtained through a year-round observations at three points of MM WB (37 GHz, 60 GHz and 93 GHz) on horizontal tracks. The information about similar parameters which are necessary for the designing of earth - space communication lines will be obtained at the expense of processing and recovery of results of atmospheric radiometric sensing in the vertical direction at 39 GHz and 94 GHz. The data about different events of abnormal or excessive atmospheric attenuation will be accompanied by in-situ contact and remote measurements of physical parameters and processes in the atmosphere. The lidar techniques and sodar monitoring of atmospheric parameters, such as its temperature inhomogeneities, the height of the cloud cover and altitude distributions of aerosols will be used to solve these problems. The special high-speed devices for in-situ measurements of intensity of precipitation, droplet size distribution, and standard meteorological parameters will be used too. This auxiliary physical information is very important for understanding the nature and subsequent modeling and forecasting of

atmosphere attenuation. The experimental and calculation radio-physical information are the cumulative distribution function of atmosphere opacity behave on vertical and ground horizontal paths, the parameters of fading oscillations of signals, the correlation of above mentioned parameters with physical processes in gas and hydrometeor components.

Separate attention will be spared to physical explanation and model description of super-strong and anomalous values and processes in the atmospheric opacity. Foremost it behaves to the events of disparity to the generally accepted theoretical understanding of abnormal values of observed opacity in clear and cloudy atmosphere at MM and in rains at sub-MM WB [15].

The obtained results will allow to fix the main negative factors affecting the signal on space-ground and radio relay systems of MM WB, to identify and estimate their impact on the propagation characteristics for different regions of Ukrainian territory, to assist to co-operating of our research team with organizations from countries of eastern Europe, whose are interesting in advancement perspective 5G networks in Ukraine.

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 transparency windows as well as experimental methods for remote monitoring of atmospheric parameters using the transceiver and radiometric equipment at MM WB and also auxiliary apparatus of lidar and acoustic sensing of the atmosphere.

On the basis of hardware backlog from KNURE, IRE NASU and KhAI in the experimental part of the research will be used:

- two horizontal measuring paths (length 600 m) with the transceiver equipment for bands 93 GHz and 37 GHz in combination with fast disdromer (measuring of the droplet size distribution) and a set of standard meteorological equipment (IRE NASU) as well as horizontal measuring path (near 100m) with transceiver equipment of 60 GHz [16-18] (KNURE, dep. RTICS). These measure systems were 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 clear, cloudy and precipitation parameters of atmosphere;
- the radiometer of 3 MM WB [19] (KhAI, dep. PRESLA) and radiometer of 8 MM WB (KNURE, dep. RTICS) were 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;
- the portable handheld sodar (KNURE, NCA) was designed for continuous remote monitoring of thermodynamic processes in the atmosphere, including the dynamics of changes in the temperature profile and its turbulent fluctuations [20];
- the lidar of near-infrared band (KNURE, dep. RTICS) is intended for RS of high-altitude distributions of the atmosphere aerosol component, height of cloud cover and

other parameters attendant for the study of abnormal attenuation events in the atmosphere.

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 propagation at MM and sub-MM WB.

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 plan in the long term to participate in the licensing implementation in Ukraine of 5G technologies. Usage of the planned results will contribute to building of formation of advanced high-speed networks on the territory of Ukraine (as part of a pan-European telecommunication space) which will base on future 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 MM WB signals will also be useful for remote sensing tasks and fundamental research environment.

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