Volume 61, Number 9
September 2018

ISSN 1064-2269

RADIOELECTRONICS AND COMMUNICATIONS SYSTEMS

Editor-in-Chief
Yuriy V. Gulyaev

PLEIADES PUBLISHING

Distributed by Springer

Abstract

Analysis of electromagnetic waves propagation of various wavelengths in the cloudy and cloudless atmosphere is presented. Attenuation of 0.8, 3.2, 5.6 and 10.0 cm radio waves in the clouds of various forms, different water content and temperatures is demonstrated. Based on the frequence and intensity of the hazards, zoning of Ukraine territory has been carried out. We have performed the substantiation of utilization of 0.8, 5.6, and 10.0 cm wavelengths for radar sounding of the atmosphere in the context of the climate and synoptic monitoring. The recommendations are given on the placement of radar stations of different frequency bands in order to meet the needs for information product of the civil and departmental aviation.

ORCID: 0000-0002-9660-8971

ISSN 0735-2727, Radioelectronics and Communications Systems, 2016, Vol. 59, No. 7, pp. 309–318. © Allerton Press, Inc., 2016.
Original Russian Text © T.E. Danova B.V. Perelygin, 2016, published in Izv. Vyssh. Uchebn. Zaved., Radioelektron., 2016, Vol. 59, No. 7, pp. 37–50.

Substantiation of Requirements to the Wavelength of Radar Monitoring for Hydrometeorological Purposes

T. E. Danova* and B. V. Perelygin
Odessa State Environmental University, Odessa, Ukraine
ORCID: 0000-0002-9660-8971, e-mail: danova8@mail.ru
Received in final form November 11, 2015

Abstract—Analysis of electromagnetic waves propagation of various wavelengths in the cloudy and cloudless atmosphere is presented. Attenuation of 0.8, 3.2, 5.6 and 10.0 cm radio waves in the clouds of various forms, different water content and temperatures is demonstrated. Based on the frequence and intensity of the hazards, zoning of Ukraine territory has been carried out. We have performed the substantiation of utilization of 0.8, 5.6, and 10.0 cm wavelengths for radar sounding of the atmosphere in the context of the climate and synoptic monitoring. The recommendations are given on the placement of radar stations of different frequency bands in order to meet the needs for information product of the civil and departmental aviation.

DOI: 10.3103/S0735272716070049

INTRODUCTION

Many of the observations in the atmosphere, which are related to the Global Climate Observing System (GCOS), are carried out in the framework of existing observing systems. The fundamental of the system of information obtaining on the state of the environment is the monitoring network, which includes a ground-based system of stationary and mobile observation points as one of its elements. This system combines the functions of the climate (the basis of climate monitoring) and synoptic (the basis of operational hydrometeorological services) monitoring [1, 2].

The most clear-cut commitments to the arrangement of devices and summaries exchange are implemented by national meteorological services at the level of surface meteorological stations network and meteorological radar stations network [1]. At the present time there are several meteorological radar stations in Ukraine [3]. Improvement of radar meteorological observations can be achieved by means of the development of a single radar field. It will provide the obtaining of hydrometeorological data continuous both in space and in time. In this case one of the first to be solved is the problem of selection of wavelength bands for each meteorological radar station, which is a part of the network.

In different countries the most efficient operating frequency band of meteorological radar stations is determined in different ways, taking into account various set of information products that is offered to the consumer. Zoning of the territory of Ukraine in order to identify regions with the highest frequence of weather hazardous phenomena, that are associated with the formation of thick convective clouds, is presented in [4–8]. Depending on the frequence of weather hazards the following priority tasks are stated for the meteorological automatic radar stations in order to minimize the damage:

– climate observations (frequence and intensity of hazards within the territory of the country);

– account of socio-economic factors, namely of density distribution of the population and the most important economic entities across the territory;

– height selection of the level of a single radar field of the country;

– the main principles of information collection and distribution.

RELEVANCE

For many years there were conducted the researches on the development of new and improvement and modernization of existing radar stations (RS) for meteorological applications. A large number of investigations is dedicated to the problem of wavelength band selection of the meteorological radar [9–16]. In most of these publications the authors considered the issue of optimal wavelength of the radar for

detection of clouds and precipitations. In response to these investigations the two-wave meteorological radar stations (MRS) of the MR-5 type, which allow one to solve the problems of hail suppression and storm warning [17], were designed in the USSR. Nevertheless, with time these stations became morally and physically obsolete and their number reduces.

The analysis of recent researches [18] has shown that the measurement accuracy of rain parameters in Ka- and X-bands is better than such for other pairs of wavelengths. In [19] the main requirements for the Doppler MRS are stated, including the requirements for the wavelength band of a meteorological radar based on the multi-criteria analysis of the long-term operational experience of coherent pulse radars. According to the recommendations of the World Meteorological Organization (WMO) for the sounding of the atmosphere for the purpose of hydrometeorological researches it is proposed to utilize radars with the wavelength of ~6 cm [19–21].

The utilization of radars with the wavelength of ~6 cm ensures the uniformity of obtained radar information when connecting to the global observing network. However, such a limitation of the operational wavelength leads to a significant loss of information, especially when it involves the indication of large-drop part of the cloud for the purposes of very short-range forecast (nowcasting). In addition, the information in the Ka-band is lost, in which one can detect unstable wind shear at the local convective processes that are hazardous for the aviation.

Against the background of lack in Ukraine of own radar engineering, which allows to provide complete environmental monitoring for meteorological purposes, the problem of development of such equipment stands on one of the first places. One of the major stages of solving the problem is the selection of wave bands of meteorological radars, which will form a single radar field. Therefore, the purpose of this investigation is the determination the approaches and the solution of the waveband selection problem of MRS taking into account the spatial distribution of hazardous weather phenomena.

The problem of substantiation of requirements for the wavelengths bands of MRS, which form the radar field of radar monitoring for the meteorological purposes in the territory of Ukraine, had not been considered before with its specific meteorological and climatic peculiarities.

SUBJECTS AND INITIAL MATERIALS OF THE INVESTIGATION

In this section we analyze the conditions of attenuation of radio waves of different wavelengths in the atmosphere (gases + water vapor) under normal conditions, in the clouds of different forms with various average water content and temperature, as well as in liquid precipitations depending on the precipitation intensity.

The initial materials of investigation are the characteristics of the atmosphere, clouds and precipitation, as well as the spatial and temporal distribution of hazardous weather phenomena in the territory of Ukraine. The calculations involved the databases of Spanish climatic site http://www.tutiempo.net/clima.htm over the period 1970–2012.

INVESTIGATION TECHNIQUES

On applied in the research theoretical level of investigation the analysis of various characteristics of radio waves during their propagation through the clouds and precipitations was utilized as the main investigation technique. In order to identify the space and time domain mechanism of development of mesoscale inhomogeneities in the investigated region we used the method of visualization of data that were obtained using the statistical processing of the investigated material.

INVESTIGATION RESULTS AND THEIR ANALYSIS

It is known that the cloud atmosphere is a system of a multitude of airborne or falling spatially distributed hydrometeors (drops, crystals, hailstones, snowflakes, graupel). From the electromagnetic field theory it is known [22] that during the propagation process electromagnetic waves interact with the environment, namely their attenuation and velocity alteration occur. The magnitude of attenuation of electromagnetic waves and their propagation velocity are determined by the electrophysical property properties of the medium.

In the process of electromagnetic waves propagation in the atmosphere their attenuation is caused by the energy absorption by atmospheric gases, and also by the absorption and scattering of energy by hydrometeors. The attenuation of radio waves is an adverse effect in the radiolocation, because it reduces the