P7.2 Non-traditional radar method of investigation of cloud environments

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1. Introduction

Non-traditional peculiarity of the given method is that new kind of information carriers detected by the author in the structure of radar echo is used. This kind of information carriers is formed during the spatial modulation of scattered radiation and is called **the spatial modulating waves** (SMWs)**.**[*] SMWs possess the increased informativeness, are not connected directly with radiated frequency, are capable due to their properties essentially to extend the functional possibilities of active radar and to increase accuracy of the measured characteristics of cloud environments. So, the following characteristics of cloud environments, becoming accessible for instrumental measurements, are:

- liquid water content averaged on dissipating volume;
- water content in investigated dissipating volume;
- aggregate state of cloud water in a dissipating volume;
- information on energetic potential of radar (version of calibration) etc.

In this case by the dissipating volume here is meant the volume of truncated cone, restricted on perimeter by antenna directional pattern, and on altitude by radial extent of video signal (Appendix 1, Fig.1).

2. The physical nature of spatial modulating waves

The analysis of experimental material showed that the fact of spatial modulation of scattered radiation concerns to the interference processes. It is impossible to detect and to understand the physical nature of which, relying only on information base of radar meteorology. Generalizing the experimental results and using a method of physical analogies, the author has come to a conclusion that during spatial modulation of scattered radiation the presence of a certain radio-optical model exhibiting properties of the spatial modulator is observed. The most close physical analog for the given type of process is the model of the flat spatial hologram. Within the framework of this model the specific mass of cloud water at excitation by falling radiation flux is capable to execute functions of spatial diffraction element. It is possible to receive insight about the linear size (period) of such diffraction element by consideration of refraction process of electromagnetic wave in a flat layer of cloud water formed by the suitable liquid water content. The analysis of such processes gives the cause to assert that at equality of intensities of scattered radiation, the mean size of periods of spatial diffraction elements and their quantity in dissipating volume will be determined extremely by variations of averaged mass of cloud water in specific volumes, i.e. variations of liquid water content. In this case the influence on linear dimensions and quantity of periods of such factors as size spectrum of hydrometeors and their geometrical shape, degree of non-uniformity of specific volumes, polarization of radiation etc., in the given method is completely eliminated (due to taking then into account through correcting factor). At such approach, the effect of modulation will be exhibited when the secondary wave front going towards the receiver (into focal plane of receiving antenna) from the category of continuous fronts will proceed into category of discrete fronts. This circumstance allows to present the essence of physical process as follows.

The wave front in the focal plane of antenna is focalized (in the diminished size) on the horn of antenna, which in its turn can be considered as a certain matrix of sensors. On the outputs of these sensors the elementary signals are formed proportionally to intensity of falling field. Further signals from sensors are amplified by the receiver and come to indicators for reproduction of images focalized on a matrix. At the same time two kinds of the images are reproduced: video signal and planar images (See Fig.2 and 3).

3. Decoding of modulating waves

As the experience shows, the formation of the planar image is conducted so, that to each sensor corresponds definite discrete interval, and the extent of this interval is determined by the value of output signal of the sensor. In other words the extent of discrete interval is proportional to the signal value from the sensor and liquid water content in space of dissipating volume. Therefore, the planar image further will be used as “sensitive” environment. It is obvious, that in order to define the mean liquid water content and supply of cloud water in dissipating volume from a

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[*] The report on detection of spatial modulating waves was published in Proceedings of 30th International Conference.

point of reception, the planar image is necessary to be splitted into the correspondent set of discrete intervals. In this case the quantity of discrete intervals should be proportional to the quantity of mean liquid water content. For the solution of the given problem into the pattern of radar the virtual reference channel is introduced. The reference channel jointly with an active channel are formed two isometric planar images, which form the shoulders of the detector working by a principle of interferometer. The channels of active and virtual radar "work" synchronically at one and the same radiated frequency, but with different environments. The characteristics of virtual environment are considered completely known and if necessary they can be tuned over a wide range. This procedure with usage of virtual environment is necessary for synthesizing parameters of comparison. The synthesizing process of comparative parameters goes at equality of intensities in reference and working channels and is supported by the software product created on the basis of radar equation and the fundamental laws of physics. The synthesized parameters of reference channel are used with parameters of active channel in different operations of comparison according to ratio algorithm. The main synthesized parameter is the **reference modulating wave**. The propagation rate of phase of given wave in considered channels is the function of cloud water located in dissipating volumes. According to method philosophy, the basis of which is the method of holographic interferometry, the reference wave are forced sequentially to pass one and the same spacing interval several times. Meanwhile the information about mean phase velocity and phase shift by an experimental method can be received if to count the quantity of discrete intervals (interference bands) formed in the corresponding images. In an analytical form such solution looks like this:

$$N_0 = \int_{t_1}^{t_2} \frac{dN_0}{dt} dt = \int_{t_1}^{t_2} F_0 dt \, , \qquad (1)$$

$$N_i = \int_{t_1}^{t_2} \frac{dN_i}{dt} dt = \int_{t_1}^{t_2} (F_0 \pm \Delta F) dt \, , \qquad (2)$$

N_0 is quantity of interference bands in the investigated and reference planar image; F_0 is quantity of discrete elements, read - out in unit of time in reference channel; $\pm \Delta F$ is Doppler shift.

The given problem is solved by imitation of displacement with specified speed of one of the subjects of location process and by definition at this displacement of the law of emission power decreases.

4. The practical solution of some problems

4.1 Definition method of correcting factor.

The presence of SMWs creates principally new possibilities, for example due to change of linear sizes (extension) of planar images to reduce them to one electromagnetic density. As a result the solution has appeared which permits to conduct the radar calibration in real time and in each cycle of measurement. The algorithm of solution was managed to be reduced to the ratio of linear sizes of two parameters possessing the identical electromagnetic density. Meanwhile one of parameters of this ratio is measured in active channel and is considered as parameter, which undertook the effect of the external and internal factors of different kinds. Another parameter (synthesized in a reference channel), displacing along a range scale, operates as though in conditions of vacuum. Therefore the ratio of these parameters in the correspondent scale, is considered as difference of energy potentials due to as internal, and external factors. The influence on an end result of some unaccounted factors is completely eliminated here.

4.2 Definition method of average liquid water content and water supply of cloud water.

To set up the solution of the given problem it is expedient to begin with acquaintance to the imagine process of location and with the analysis of illustrations of Fig.1 ÷ 4 (Appendix 1). In this appendix Fig.1 and Fig.3 are considered equivalent in information content. However, the further main information source becomes the planar image with extent of $L = R10^{0,1n/2}$. According to method philosophy in this "sensitive" environment the definite quantity of discrete intervals (interference bands), which generate the order of interference, is recorded also. In other words given environment is " not developed " planar hologram. Therefore, the next stage is "development" of given medium and extraction from the hologram of that information, which on it is registered. Technologically this stage consists of motion imitation of one of the subjects of location process, quantization of the planar image and registration of relative changes of the diaphragm aperture a, b, c (Fig.3). Further definition problem of average liquid water content and water supply in an investigated dissipating volume becomes simple and does not cause difficulties. On physical essence this problem is a way of "weighting" of cloud environments with the help of electromagnetic waves.

4.3 *Improvement method of radio visibility in conditions of masking action of precipitation and fog.*

Removal method of masking action of precipitation and detection method of scatterers in solid phase (estimation of aggregate condition of cloud water) by physical principal is similar. As the experience shows the appearance in volumes with cloud environment V_1 or V_2 (Appendix 1) some local heterogeneities leads to the modification of the hologram structure of these volumes. The difference in electromagnetic density of volumes V_1 and V_2 is valued relatively their mean electromagnetic density. Further with the help of the patterns of the correspondent holograms it is possible to identify the local non-uniformity. The local changes of electromagnetic density of the indicated volumes can have the natural or artificial character. By a scanning method on scale of spacing intervals it is possible to define not only coordinates of these local heterogeneities, but also to define more exactly a number of other characteristics.

5. References

1. Sivukhin, D. V., 1980: Obshchij kurs fiziki, optika.
2. Kremer, I. Ya., 1984: Prostranstvenno - vremennaya obrabotka signalov.
3. Bolshakov, V. D., 1985: Radio - geodezicheskie i elektro - opticheskie izmereniya.
4. Trofimova, T. I., 1999: Optika i atomnaya fizika.

Appendix 1

Scheme of radio hologram construction