RADAR TECHNIQUES OF METEOROGICAL EVENTS DETECTION BY POLARIZATION CHARACTERISTICS OF SIGNAL

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During the flights in the severe meteorological conditions the thunderstorm clouds, zone of the increased turbulence, hail and intensive precipitation are the most dangerous phenomena. Up to present considerable theoretical and experimental materials related to the investigation of possible means of the detection of the listed meteorological phenomena using radar equipment are collected.

In the meteorological radar operation the technique of the detection of the thunderstorm clouds danger is applied basing on variation of the vertical profile of the radar reflectivity.

This technique is based on the fact that in the profile of the vertical reflectance a well-marked maximum is revealed in the field beneath zero isotherm, i.e.

$$Y = H_{max} \operatorname{Ig} Z$$ - criterion of thunderstorm danger

Polarization technique has a significant advantage comparing with the above mentioned techniques.

First, the hail processes are always accompanied by the electric discharges. That is why any of the technique of the detection of thunderstorm clouds danger allows to identify the clouds which are dangerous due to their electric activity.

Second, the polarization characteristics of the electrically active clouds have peculiar features which distinct them from the common cumulo-nimubus. These peculiarities are related to the orientation of the ice crystals or deformation of drops cause by the electric field. First time this effect was detected in experimental way in optical band by different changes of the solar light reflected from the cloud crystals during the thunderstorm discharges. Later it was detected with the radar signal by the change of depolarization value on circular polarization which occurred simultaneously with the lightning discharge. However, in average, the value of polarization was near the polarization value in non-thunderstorm cloud.

In cumulo-nimubus the differential reflectivity in the layer above zero isotherm is near 0 dB. With the occurrence of electric field the differential reflectivity for the clouds producing discharges of the cloud – ground type is negative and is -0.4 – 0.6dB, while for the discharges between the clouds the value of differential reflectivity is more than zero and is 1,5 – 2,5 dB. The typical features of the temporal trend of differential reflectivity during cloud – ground discharges are sudden changes from 0.4 to 0.6 dB simultaneously with the electric discharge.

During the measurement of the turbulence in clouds and precipitation the difference between the Doppler radar frequencies of the adjacent resolvable volumes when using non-coherent radar station is used. The signal received from radar station after the amplitude limitation is transmitted to the first input of the phase detector, while the same signal is transmitted to the second input with 3,3 microsecond delay. With this, in the output of the phase detector a signal appears which is proportional to the difference between the phases of signals from the reflecting volumes shifted along the radar beam 500 m one from another. The difference between phases is saved until the next impulse when it is subtracted and similar difference on the next impulse.

If the relative velocity on the two mentioned volumes equals zero, then the mentioned phase difference is zero, too. The fields with the increased phase difference can be identified as the areas with the increased turbulence.

If the clouds are of the mixed character, then the echo is formed both by the drops and crystals, and its depolarization differs from the depolarization of the homogeneous clouds.

The value of depolarization in the mixed cloud can be calculated by summation of echoes reflected from the both cloud components separately for each orthogonal plane. Thus, we derive the following formula for the estimation of depolarization from the mixed cloud:

$$\Delta P_{1mixed} = \Delta P_{1cr}\{(\eta II_{drops} / \eta II_{cry}) + 1\} - 1 \qquad (2)$$

Here ΔP_{1cry} - is the polarization value which can give the purely crystal cloud; $\eta II_{drops}/\eta II_{cry}$ = m - is the relationship between the share of drops in the radar reflectivity of the drops and crystals. Fig. 1 shows that when the drop contribution to the radar reflectivity is much more (10-15 times), than the crystal contribution, then the impact of the last ones is almost negligible, i.e. the depolarization component is sensitive to a small number of crystals.

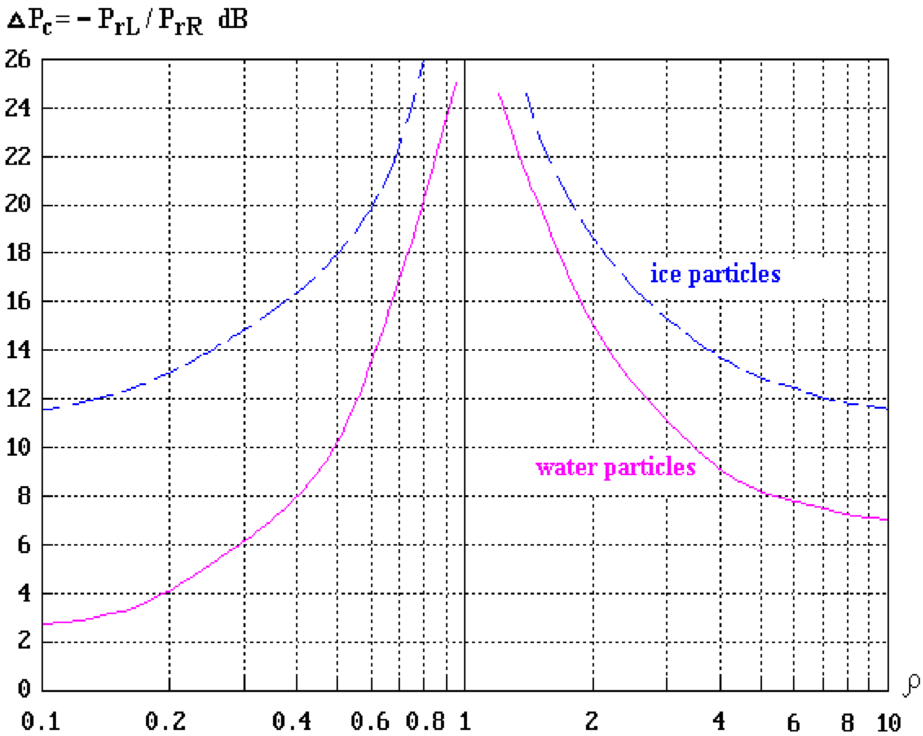

Fig.1 Relationship between the factor of circle depolarization and the particles form

The simultaneous changes of depolarization and differentional reflectivity extend the possibilities of polarization techniques in the definition and study of microphysical and integral characteristics of the clouds and precipitation significantly.

Let's consider the results of computed values of differential reflectivity of crystal clouds using the horizontal radar sounding at different elevation levels.

The most probable shape and form of the crystals is given vis the air temperature. Calculation for the needles (cylinders) is made at their arbitrary orientation in horizontal plane while for the plates (disks) it is given in the vertical plane (Table 1).

Table 1

Table of calculated values of differential reflectivity of crystal clouds at the horizontal radar sounding at different elevation

Air temperature, °C	Type of crystals, shape	ZdR
-2÷ -5	Thin plates 1:50, 1:100	9.1 ÷9.7
-5 ÷ -7	Needles 1:10, 1:50	3.4 ÷ 4.8
-7 ÷ -10	Thin plates 1:50	9.1
-10 ÷ -16	Thick plates 1:10	7.7
-16 ÷ -20	Columns 1:5, 1:10	2.7÷3.4
-20÷-30	Columns and three-dimensional form 1:5, 1:3	2.0÷2.7
-30÷-35	Columns 1:5, 1:10	2.7÷3.4

As ZdR does not depend on the concentration of dissipative particles, then comparing the obtained ZdR values with the table values it is possible to estimate the relative contribution of drops and crystals separately to the reflectivity , i.e., to get the value characterizing the mixture.

With the known relationships between the drops and crystals in the cloud or its zones it is possible to determine the probability of icing.

Polarization technique of detection of possibility of hail fall from the cloud was based on the measurements of depolarization value.

During the measurements with the radar it was found out that the hail was falling from the cloud in the cloud zone where the depolarization was more then 10 … 12 dB.

The application of differential reflectivity in the radars with the double polarization allows not only more accurate detection of hail presence in a cloud, but also to decrease the reflectivity level to such extent when the hail presence definition is possible since 32-35 dB using only depolarization and up to 27-28 dB with the differential reflectivity.

Finally, it should be noted that polarization techniques provide for the detection of the dangerous meteorological formations, to identify the reflection sources, to monitor the environment and to apply them in the solution of the applied problems on the atmospheric studies and relevant processes.