Simulation Study of Relationships between Doppler-Polarimetric Parameters at Microwave Remote Sensing of Precipitation

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Abstract— **This paper studies the relationships between recently introduced differential Doppler velocity and other parameters of radar signal reflected from rain. Analytical calculation and simulation methods are used mostly. The results are checked by measurements in special cases. Some possibilities to derive information on distributed object structure are shown.**

I. INTRODUCTION

Doppler-polarimetric techniques step by step become needed not only for research works but for practice of radar remote sensing. In our previous work [1] it was proved experimentally that differential Doppler velocity (DDV) can be related with turbulence intensity within resolution volume in case of remote sensing of rain. It is also known that Doppler polarimetric observation of clouds and precipitation is characterized by significant number of measurable variables [2], or measurands. Recently spectral differential reflectivity and other functions and parameters were introduced [3], [4]. The information potential of the data becomes higher, but also processing is more complicated. Because of complexity, sometimes it becomes very difficult to implement signal processing in real time that results in restriction of practical applications of new promising scientific achievements. That is why operative radar data interpretation to derive necessary information arises as very important problem. A number of Doppler-polarimetric measurands that together with conventional parameters like reflectivity and Doppler spectrum width can be associated with desired parameters of weather objects. For more effective data interpretation it is important to understand how different measurands are related between themselves. This information obtained under the different conditions is necessary to derive useful information about objects under study by reflected signal analysis.

In this paper we develop models and fulfil calculations for wide variety of Doppler polarimetric parameters to study their relationships between themselves and with the features of reflected objects.

II. MODELS OF THE SPECTRA

The model developed earlier [1], [3] was modernized to calculate basic Doppler polarimetric parameters and relationships between parameters and objects under study. As initial data we use the following suppositions.

The scatterers are water drops. There is a minimum $D_{\min}$ and a maximum $D_{\max}$ possible drop diameter in a rainfall or cloud. Dropsize D distribution is described by gamma model

$$N(D) = N_0(\mu, D_0)D^{\mu}\exp\left(-\frac{3.67+\mu}{D_0}D\right), \tag{1}$$

where function $N_0(\mu, D_0)$ is calculated under the condition that concentration parameter $N_0 = 8000$ [mm^{-1}/m^3] in case of empirical Marshall-Palmer model [5], μ is dimensionless spread parameter, D_0 is equivalent median diameter of drops in mm, which is related with rain rate R as:

$$R = 6\cdot 10^{-4}\pi \int_{D_{\min}}^{D_{\max}} N(D, \mu, D_0)D^3 v_f(D)dD \tag{2}$$

where $v_f(D)$ is terminal drop fall velocity. Based on Stokes law we approximate $v_f(D)$ as

$$v_f(D) = \begin{cases} 9.76\left[1-\exp(-0.55D)\right] & \mathit{if}\ 0 \le D \\ 0 & \mathit{otherwise} \end{cases} \tag{3}$$

Distribution of scatterer velocity induced by turbulence that acts inside the resolution volume can be modelled by expression derived in [6]

$$W(v_t) = \frac{\pi^{-1/2}}{L_m^{2/3}\xi^2}\left\{\begin{array}{l} \sqrt{2}\xi\left[L_{\max}^{1/3}e^{-\frac{v_t}{2L_{\max}^{2/3}\xi^2}} - L_{\min}^{1/3}e^{-\frac{v_t}{2L_{\min}^{2/3}\xi^2}}\right] + \\ \sqrt{\pi}v_t\left[erf\left(\frac{v_t}{\sqrt{2}L_{\max}^{1/3}\xi}\right) - erf\left(\frac{v_t}{\sqrt{2}L_{\min}^{1/3}\xi}\right)\right] \end{array}\right\} \tag{4}$$

with $\xi = C_0^{1/2}\varepsilon^{1/3}$ where ε is a measure of turbulence intensity called eddy dissipation rate, and C_0 is a dimensionless