

# New Applications of Low Cost Rain Sensor "DROP"

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## 1. Introduction

The Low Cost Rain sensor (LCR) "DROP" is the micro power continuous operation Doppler type radar. The details of principle of operation and the construction of the device were reported at TECO-2005. The device was successfully tested on the hydro meteorological experimental site of Hydro Meteorological Service of Russian Federation at Valday Lake within summer seasons 2004-2005. Then, the State Certificate was received in 2006, which approved "DROP" as an official tool for liquid precipitation measurements. It was started the experimental implementation of rain sensors "DROP" on observational net of Roshydromet since summer season 2006. The first results of this work were reported by authors at TECO-2006.

Recently two new possible applications of LCR "DROP" were developed. The first application is intended to introduce "DROP" as a 'present weather sensor' on automatic weather stations. Such a possibility is based on the increasing of the working frequency of the device. It is well know a number of meteorological radars operating at the frequencies 70GHz and up for fog study. For this purpose, it was tested different Very High Frequency module to replace current VHF module of LCR "DROP". And namely it was modules operating at 60GHz. The results of these tests, as well as advantageous of each frequency operation are discussed in the report.

The second new application is possibility to use LCR "DROP" as a disdrometer in case of study or operative analysis of the rain microstructure. It is well known the method of "inverse task" solution, when the drop size distribution is retrieved from measured Doppler spectra. We have tested absolutely different idea, when the "foot print" of each individual drop is analyzed on a real time spectrogram. Spectrogram is an isopleths plot in coordinate time versus frequency and third coordinate as a reflected power. Such an approach is very common now in MST radars to compress interference errors, and it is presented in the report that the same idea is very productive in rain microstructure measurements.

## 2. Possibility to use LCR "DROP" as a present weather sensor.

As it was described yet (Koldaev et.al 2005), the principle of measurements of rain parameters by LCR is based on the measurement of the backscattering of the radio waves by the rain drops. At the working frequency of LCR , which is 10.6 GHz, the rain drops are "Relay" scatters

$$\frac{\pi D}{\lambda} \ll 1 \quad (1)$$

Thus, for the backscattering cross-section the next equation is applicable (V.D. Stepanenko, et. al 1987 ):

$$\sigma(D) = N_o \frac{\pi^5}{\lambda^4} |k|^2 D^6 \quad (2)$$

Where K is well known function of complex dielectric index of water,  $\lambda$  is wavelength of the

sounding wave (for 10.6GHz it is equal to 2.8 sm)  $D$  is rain drop diameter.

It is easy to see from equation (2) two facts: 1- with the decrease of the working wavelength (or frequency increase) the backscattering cross-section will increase proportional to 4 power of it; 2- the cross section of the drop with 0.5mm diameter will be in million times smaller than the cross-section of the drop with 5mm diameter. It is consequent from these facts, that if we would use LCR for measurement of the drizzle with average drop diameter around 0.5mm, we will get the output signal at about 40DBz less than from the average rain with mean drop diameter 3mm. It means that drizzle almost invisible by LCR, and the fog, which has much smaller mean drop diameter, can not be even detected by LCR. According to (2), there is only one possibility to increase “sensitivity” of the radar-type rain sensor – just to increase the working frequency. However, if we will use the instrument with 60GHz working frequency, thus the Ray assumption will not be applicable even for the drizzle-size drops and Me equations will describe the scattering process:

$$\sigma(d) = \frac{2\pi}{k^2} \sum_{n=1}^{\infty} (2n+1)(|a_n|^2 + |b_n|^2) \quad (3)$$

Where  $a_n$  and  $b_n$  are super positions of the Bessel and Henkel functions and their first derivative along the argument, which is product of dielectric constant and Ray parameter  $\frac{\pi D}{\lambda}$  (V.D. Stepanenko, et. al 1987).

From this last equation it is obvious that there is no any definite connection between any momentum of DSD with the measured power back scattered by the Me type scatters. So increasing the working frequency can provide sufficient benefit with the sensitivity to the different type of the hydrometeors, but will not provide quantities measurements of their parameters. On this base we can speak just about detecting of the different hydrometeors by the systems analogies to LCR, but operating at the much higher frequencies or so called “present weather sensor”(PWS)

Nevertheless, it is necessary to point the attention to obvious difficulty of usage high frequency LCR as a PWS. From (3) can be easy calculated that the different event as deep fog and light drizzle can indicate the same back scattering cross-section. In this situation, the analysis of the Doppler spectra measured by LCR type sensors can allow us to distinguish the different events and make proper identification. The utilizing of high frequency systems may help in this case also. It is well known that the Doppler frequency is given as

$$f_d = \frac{2V}{\lambda} \quad (4)$$

Where  $V$ - is an average hydrometeor fall velocity.

It is easy to see from (4) that Doppler frequency will increase with the decrease of the wavelength of the sounding wave, so slow falling hydrometeors as drizzle will be much better distinguished by high frequency systems.

On the base of the above mentioned features we have constructed the Tab.1, which summarize the advantageous of the use of high frequency LCR type systems for present weather sensing. The table was constructed on the base of calculation with the use of the equations (2)-(4) above and the average parameters of the hydrometeors from (V.I. Rozenberg. 1972). In the presented tables were accepted the next titles: “Meteorological Event”- type of the hydrometeors observed in the near ground atmosphere; “ $V_{av}$ ” – average speed of hydrometeors sedimentation; “ $D_{eff}$ ” – effective radius of particles corresponding to the definite event;  $P_{60}/P_{11}$  – ratio in dB of the output value for the LCR –type system operating at 60 GHz and 11 GHz;  $f_{d60}/f_{d11}$  – are two values in Hz for average Doppler velocity for the 60GHz and 11GHz sounding waves.

Meteorological Event	Vav[m/sec]	Deff[mm]	P60/P11[dB]	$f_d 60/ f_d 11$ [Hz]
Rain	5	3	49	2000/357
Wet snow	2	8	62	800/143
Dry snow	1.5	1	38	600/107
Drizzle	0.5	0.5	33	200/36
Fog	0.01	0.05	30	4/0.7

Table 1: Theoretically expected benefit of the use 60 GHz working frequency in LCR for the present weather sensing.

It can be seen from the Tab.1 that the usage of 60 GHz working frequency is really providing the function of PWS for the LCR-type instruments.

### 3. Disdrometry of the rain drops by the LCR “DROP”.

It is obvious from the principle of operation of Doppler radar type rain sensors, that the information about Drop Size Distribution (DSD) is present in the measured spectra in indirect form. If each drop would make delta-function output on the Doppler spectra, thus the reverse task will have simplest solution because in this case each spectral interval can be referred to the definite drop size. However, each drop produces a kind of spectral output with certain width due to the geometry of measuring volume and speed of the drop (Sheppard 1990). In the same work, it was proposed the algorithm to solve non-correct reverse task to retrieve the DSD with some accepted probability. The experiments, presented by (Sheppard 1990) demonstrated very promising results. However it was “retrieved” distribution with the definite norm of probability.

Meantime, in coherent radar technology, there is a type of information presentation in form of spectrogram and it is used in MST -radars about 10 years yet. The spectrogram is 3D plot, where Doppler radar output is presented in coordinates of frequency versus time. The third coordinate is presented in color and correspond to the intensity of the reflected signal. In MST radars this type of information presentation is widely used to eliminate signals from the clutters and artificial objects like air jet.

We have used this type of Doppler radar signal presentation by utilization of the standard LCR-11. But the signal from the low frequency amplifier of LCR was directed to the PC sound card. Then the FFT software was used to construct the spectrogram. One of the examples of the rain record with the use of this procedure is presented on the Fig.1a. It is well seen that all drops falling with the terminal velocities makes individual “foot print”. It is parallel to the time scale at the beginning and then the “tail” comes or to zero frequency or is parallel to the frequency scale at the end. This “tails” can be easy explained by the picture on the Fig1b. Because the LCR is measuring the projection of the falling velocity on the direction of sounding, the drop velocity will decrease as a cosine of the sounding angle counting from zenith direction. So while the drop is on the traverse of LCR, the projection is zero, and the measured Doppler frequency coming to 0 also. There are cases when drops fall down on the Radom of LCR. In this situation the velocity is changed immediately to 0, and the FFT gives very wide spectrum from zero to maximum frequency. The observed spectrogram provides visible explanation of the Doppler spectra calculated by LCR within tenth of seconds or minutes: it is just an integral of all drops spectral “foot prints” along the time scale. The integration of all “tails” makes really non-correct the reverse task of DSD retrieval from the integral Doppler spectra. But the utilization of the

standard sound card allows making the immediate picture of the drops existing in the measurement volume. Count of the drops of different diameter (separated along frequency scale) is absolutely correct and not complicated algorithmic task.

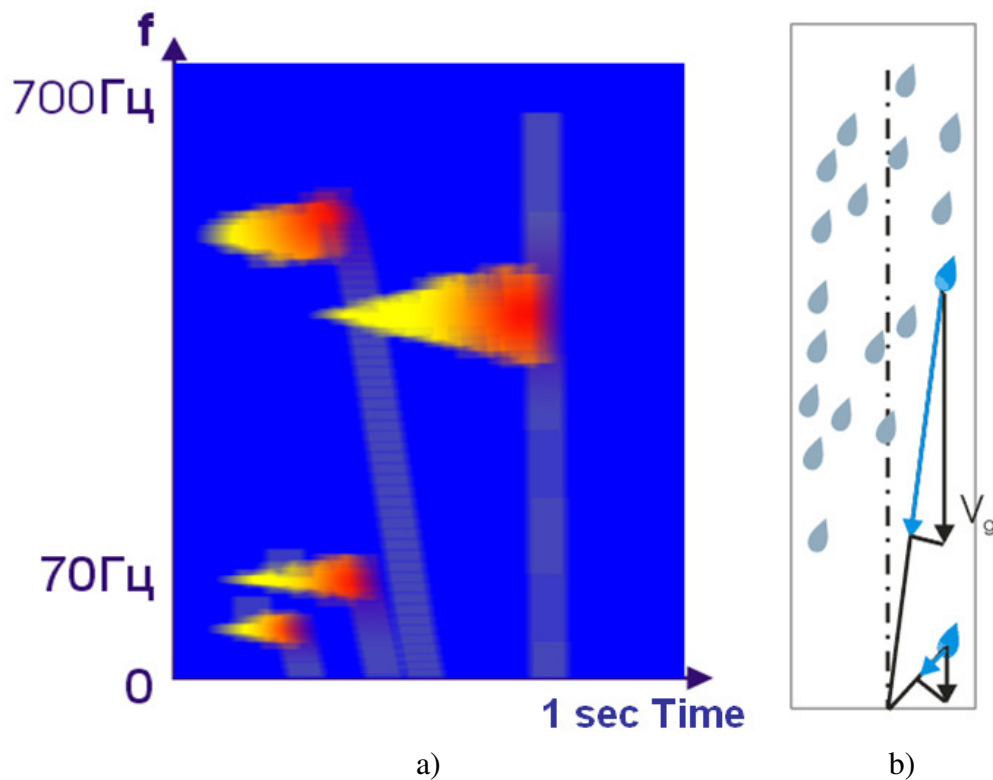


Fig.1 Example of the rain spectrogram measured by LCR with sound card (a) and illustration of the sounding geometry (b).

## References

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