METHODS FOR INCREASE ACCURACY AND REDUCE THE AVERAGING TIME IN PRECIPITATION INTENSITY MEASUREMENT FOR RADIOWAVE PROPAGATION INVESTIGATIONS

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Abstract

Accurate measurement of the precipitation intensity and collection of sufficient data for them is an essential prerequisite for precise prediction of attenuation of radio waves and the reliability of the radio links at frequencies above 10 GHz. The available data from meteorological services are not appropriate because their intensity averaging time is great and it does not allow recording peaks of the intensity. Moreover, some of the methods of measurement do not allow sufficient measurement accuracy for heavy precipitation, which have an important role in the interruption of the radio links.

Two methods of measurement to improve accuracy and reduce time for averaging are proposed in this paper. The first is a combination of the two main existing approaches - the tipping bucket and weighing methods. It allows more accurate registration of heavy rainfall intensity. The second method is based on the non-linear transformation of precipitation (water flow) in water level (weight) and measurement of this level. It allows maintaining good relative accuracy of measurement and it is relatively simpler than the first one.

1. INTRODUCTION

The attenuation of the radio waves in hydrometeors significantly affects the functioning of the radio links operating at frequencies above 10 GHz [1]. The methods for predicting and evaluating the attenuation in such conditions, are largely based on rainfall data from the meteorological services in different regions of the world. This data is not always suitable for the needs of the communications [2, 3]. Most often, the period of time taken in consideration for averaging the rainfall rate is relatively large and this leads to not accounting of the peak values of the rain rate, which would result in extreme attenuation of the radio waves and therefore to a possibility of disruption of the radio links for a certain, although relatively small, period of time.

In some cases, are made attempts, based on the collected precipitation data with relatively large averaging time to be restored the true picture of the rain rate, i.e. to be obtained the actual values of the rain rate for smaller intervals of time during the period of averaging only by the average rain rate for this period based on a statistics for the relationship between these parameters for other regions.

Moreover, some of the main methods for measuring the rain rates does not allow sufficient accuracy at extreme values of the rain rate [4].

In the present work, two methods for measuring the rain rate are proposed, they are based on the previously existing methods, but allow avoidance of the disadvantages in terms of communications, in particular averaging the values for small enough period of time and providing higher accuracy at high values of rain rates. Furthermore they are complied with the achievement of relatively low price of the monitoring devices.

In the analysis of the main parameters of the devices, which will be developed, based on these methods, is taken into consideration the statistics of precipitation for the territory of Bulgaria and the attenuation model for radio wave propagation in precipitation.

2. METHODS FOR PRECIPITATION INTENSITY MEASUREMENT, ALLOWING REDUCTION OF THE AVERAGING TIME AND INCREASING THE ACCURACY

2.1. Method for precipitation intensity measurement, based on measurement of weight and tipping bucket system

2..1.1. Structure and principle of operation

A major problem in determining of the rain rate, by measuring the weight of collected water from given area covered by collecting device, is providing of fast enough procedure of emptying the container in which the water is collected, in order to measure water's weight. If this container is with small volume, which will allow its rapid emptying, then it will be difficult to be registered the rain rates with high values. If the volume is large enough to allow registering of high values of rain rates, the container will be emptying for a relatively long period of time and this will lead to failure measurements for this period and thereby the loss of data, especially at high values of rain rate. Therefore, in the proposed method, the water from the precipitations is collected and measured in the reservoirs on tipping bucket mechanism (Figure 1), which allows fast emptying after filling. Their volume should be large enough so that not to be necessary too frequent emptying of them and therefore losing of measurement records.

The principle of operation of the proposed device consists of the following: water from the precipitations covered by the surface of the collecting device (1) falls into one of the reservoirs of the tipping bucket mechanism (2) and is measured by the weight sensor (4).

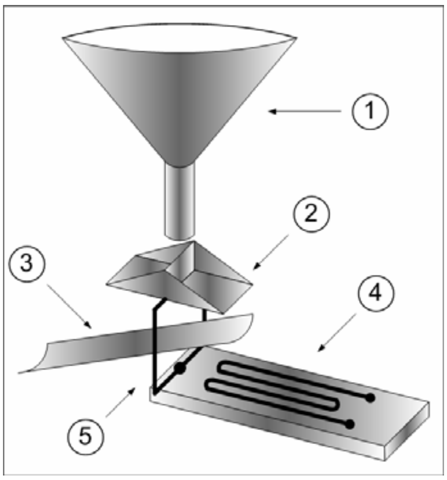

Figure. 1. Scheme of device for measuring the rain rate based on measurement of weight and tipping bucket mechanism

When one of the reservoirs fills up, the rocker turns upside down and the reservoir empties, while the other reservoir starts to fills. The water from the reservoir is conveyed by special furrow (3) in order not to fall on the sensor. Thus, the release of water from the container in which it is collected for measuring is relatively fast compared with the time for its filling.

2..1.2..Analysis of some of the main parameters of the measuring devices

For the purposes of the measuring of instantaneous values of rain rates it is necessary to select a suitable averaging time t_{av}. It is the interval between two records of the weight of the water from the fallen precipitations and for the purposes of measuring the attenuation of radio waves from the millimeter range it should be small enough. For example, when the desired reliability of the radio link is 99.9999% of the time, i.e. on an annual basis is allowed no more than 32 seconds disability. Therefore the interval t_{av} must be much smaller and can be chosen t_{av} = 1 *s*. On the other hand the operating range of the udometer should be selected, in order to ensure accurate reporting of the rains that could affect the propagation of the radio waves. For maximum value of the intensity of the rain can be chosen RR_{max} = 400 mm/h. When choosing the minimum value RR_{min} on the other hand, some parameters from constructive character must be considered. It will depend on the size of the collecting device S, the averaging time t_{av} and the resolution of the sensor weight Δm. The following equation (1) shows this relationship:

$$RR_{\min} = \frac{3{,}6.\Delta m}{S.t_{av}}. \qquad (1)$$

In Figure 2 is shown the graph of relation (1) for several values of Δm from weight sensors that are available on the market.

From the graph can be selected reasonable values for the size of the area of the collecting device and the minimum value of rain rate, which can be recorded since they can determine other constructive parameters in terms of the maximum rain rate value.

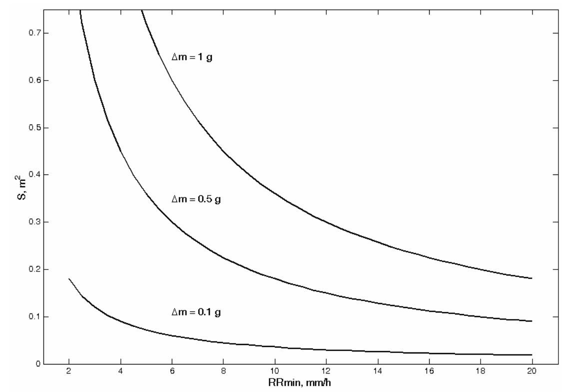

Figure. 2. Dependence of the area of the collecting device and the minimum rain rate

Equation (2) reflects the relationship between the volume of the one chamber of the tipping bucket system V in cm^3 and the surface of the collecting device S for a maximum rain rate:

$$V = \frac{t_{\max}.RR_{\max}.S}{3.6}, \qquad (2)$$

where t_{max} is the time to rollover the tipping bucket mechanism. This reversal is associated with short-term interruption of the recording process and should happen on large intervals of time in order to approximate the lost reports based on the other values. According to our estimates, it should be 20 to 50 times greater than the averaging time.

Figure 3 shows a graph of relation (2) for several values of t_{max} at RR_{max} = 400 mm/h.

Through the thus obtained relationships it can be selected an optimal combination of construction and operating parameters of the udometer so that it will allow measurements for the purposes of accounting of the attenuation of electromagnetic waves from the centimeter and millimeter bands in rain, which will be the subject of future research and experiments.

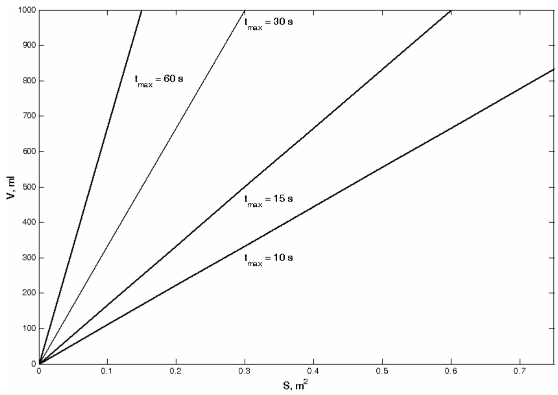

Figure. 3. Dependence of the volume of the one chamber of the tipping bucket mechanism from the area of the collecting device

2.2. Method for measuring the rain rate through nonlinear transformation of the intensity of precipitation in weight

In the second proposed method, the rain rate is transformed into water level, respectively, in the weight of the water collected by the device shown in Figure 4.

The water from the collecting device (1) is poured into measuring cone (2), which has a slot with variable width from which a part of the water flows into a special furrow (3). When the precipitation is weak, the water level in the measuring cone will be low, therefore the water that will flow through the slot will be less. In heavy rains, the level will increase and the amount of water that pours from the measuring cone will also increase and in such manner a non-linear transformation of the intensity of precipitation to water level (respectively the weight of water in the measuring funnel) is obtainned, which can be register with the weight sensor (4).

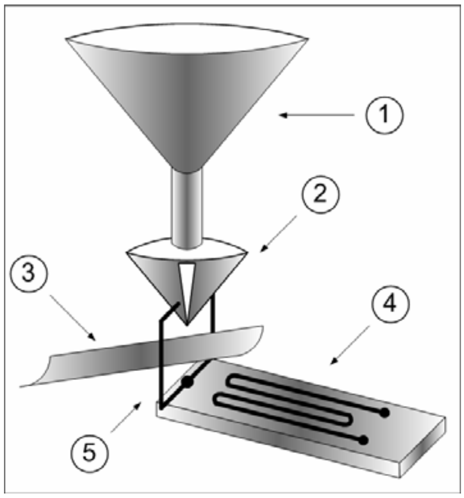

Figure. 4. Scheme of the device for measuring the rain rate with nonlinear transformation of the amount of the precipitation in level (weight)

Thus the rain rate is transformed into water level, while it is kept a relatively constant accuracy throughout the whole range of variation in the rain rate values. The shape of the slot, its size and the size of the measuring funnel will be the subject of future experimental work.

3. ACKNOWLEDGMENTS

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