ACOUSTIC DATA LOGGER FOR DRIPPING AND LEAK MONITORING

AKUSTICKÝ DATA LOGGER PRO SLEDOVÁNÍ KAPÁNÍ A ÚNIKŮ

David VARNER

Abstrakt:

Článek přináší informace o výsledcích vývoje a testování akustického kontaktního data loggeru na počítání kapek (kapkoměru). Toto zařízení je určeno k dlouhodobému fungování v libovolném prostředí bez zásahu obsluhy. Během vývoje byly stanoveny a vyřešeny hlavní otázky a požadavky na kapkoměr. Výsledky naznačují, že vyvinuté kapkoměry jsou dostatečně robustní, spolehlivé a snadno použitelné i neproškoleným personálem. Tato zařízení mohou být použita v průmyslových i environmentálních aplikacích dle specifických požadavků výzkumu. V rámci případové studie je činnost kapkoměru demonstrována při nasazení v jeskynním prostředí za účelem sledování vydatnosti (kapání) skapových vod.

monitorování, kapání, úniky, skapové vody

Abstract:

The paper presents results of independent development and prototyping of an acoustic contact-based data logger (called dropmeter). This device is intended for long-time standalone operation in any hostile environment. During the design phase, all vital characteristics of the device were analyzed and integrated in the project. Results indicate that the dropmeter unit is robust, reliable and easy-to-use even for non-trained personnel. It might be used in any industrial and/or environmental research as required. As a case study, the device was successfully tested in a karst cave for counting of drip water discharge.

monitoring, dripping, leaks, cave drip waters

1. INTRODUCTION

There are many industrial and agricultural processes that include liquid (water) medium which is prone to leaks. In order to assess the leakage nature and intensity, it might be useful to monitor liquid flow by means of individual drop counting. Not many industrial solutions have been available that would be both effective and affordable. This paper describes design, development, and testing of a standalone data logger device (dropmeter). For initial evaluation of operation reliability, cave dripping water was chosen as a natural source of drops. This process features stochastic pattern somehow dependent on surface rainfall and seepage path through the limestone massive. It is worth noting that the dropmeter may be deployed in and environment and/or application where exploration of time dynamics for the leak/flow becomes critical.

For a long period of time, the only "automatic-like" method for drip discharge monitoring had been the tipping bucket. As described by Oblack (2007), a tipping bucket rain gauge is a meteorological device that measures the amount of precipitation, or rain, which has fallen. It is one of the most common tools used to measure rainfall. Quite an innovative approach was showed by Genty and Deflandre (1998). Authors used special automatic stations that had been constructed specifically for cave research project by RSH Company. All the data including air temperature/pressure, water pH/conductivity, number of drops and discharge volume) were stored in a RAM memory every 10 min for further processing. Tooth and Spötl (2001) recorded drip data using data loggers which continually measure drip rate and EC. Moreover, monthly cave visits were carried out to collect special samples and drip rate information was recorded. An array of automatic drip water sampling stations was installed in two large chambers, which sample drip waters from stalactites feeding actively growing stalagmites.

Cruz, Magdaleno et al. (2005) monitored cave waters using the Davis automatic tipping bucket coupled to an Onset Logger, model Hobo for 8000 events. Continuous monitoring of cave drip sites was successfully implemented by McDonald and Drysdale (2007) and McDonald, Drysdale et al. (2007). Dripwater samples were analyzed for pH, electrical conductivity, cations and anions. The drip discharge was monitored continuously at six sites and manually at four sites. The automatic discharge monitoring system included a fork sensor with infrared (IR) sensor, and Tynytag Gemini data logger. An impressive underground laboratory was used by Fernandez-Cortes, Calaforra et al. (2007) in the Cueva del Agua cave in Spain to monitor infiltration processes. The station included an outdoors meteorological station, and two interior stations: one to monitor dripping discharge from a stalactite and one to a second station that records the barometric air pressure inside the cave. Innovative monitoring method was used by Sundqvist, Seibert et al. (2007). An automatic sampling station registering drip rate, relative humidity, and temperature was installed in the Korallgrottan cave in June 2000 and continuously deployed till October 2006. Mattey, Fairchild et al. (2010) used automatic data loggers in New St. Michaels Cave to uncover annual growth laminae development. Three drip water sites were monitored and automatic drip loggers provided vital information that could not be obtained using any other method. Shone (2012) reported a brand new sampling system in the Bärenhöhle in Voralberg. Collecting vessels were installed using a rope framework to lead the drip water to the very heart of the monitoring system. A custom made automatic water sampler can collect drip water samples from a stalactite at twelve hour intervals making the sampling very high resolution.

2. MATERIALS AND METHODS

Development of the Device

Some overall design features (CPU, memory, battery, connectivity) of the device were obvious and similar to any industry-standard data-loggers. However, a substantial part of the development process was dedicated to exploration of dripping process itself. To capture the signal with high reliability rate, it was necessary to simulate the actual drop impact and optimize response of the device. Dripping water impact waves were simulated in common shower experiment with variable drip height values and impact plate slopes.

Simulations revealed that growing drip height increases amplitude of the signal. However, the 1st harmonic remained fixed at 1.55kHz. Thus, this band could be evaluated by narrow-band amplifier and further processed by analogue comparator. The output was then forwarded to low-consumption counter which provided the data to CPU. Figure 01 shows FFT-processed frequency response of the unit during a simulated drop fall (height of 50 - 70 cm).

3. RESULTS

The dropmeter represents a unique data logger device that is capable of continuous recording of drip water discharge. The electronic device is placed in watertight aluminium-made case. Acoustic signal generated by drop impact is stored into EPROM memory for further processing. The connection with control PC is done via standard mini USB connector with a rubber closure (see Figure 02).

Main technical features of the device are as follows:

- *Power voltage: 3,7VDC ± 30%*
- *Battery (primary/backup): 2 x UR18650F/Lithium CR2032*
- *Main Sensor: Piezoelectric crystal in unit cover*
- *Maximum detectable drip discharge: 4 drops per second*

- *Recording time (full battery life): Approximately 4 years*
- *PC connection type: Mini USB*
- *Operation temperature range: - 20°C to + 60°C*
- *Operation air humidity range : 0% to 100%*
- *Overall weight: 550g*
- *Overall dimensions: 45 x 65 x 150 mm*

The dropmeter is a very easy-to-use device. Once brought to the place of operation in the cave, it ought to be fixed to a common camera tripod. The tripod must be placed carefully to compensate for complex shaped surface of the cave floor. This is done simply by adjustable length of the tripod legs.

The dropmeter setup and data transfer are managed using proprietary software for MS Windows. The **Dropmeter software** requires a driver and a COM port to successfully communicate with the dropmeter unit. The software is started by double-clicking the application's EXE file. The main application window displays containing a menu bar, bottom bar drop-down list and the following tabs:

- **Save Data** tab (download of recorded data, see Figure 03)
- **Configuration** tab (current time and date, recording interval, memory erasure).

To test reliability of the new device, two dropmeter units were been exposed in Kateřinská Jeskyně Cave (Moravian Karst). The testing proved that they withstood hostile conditions of limestone cave environment. After 3-month exposition in the cave, both dropmeters were found intact and fully functional. Dripping count data was successfully retrieved for further processing. The only change found was a slight calcite coating on the dropmeter box and minor corrosion of two small steel bolts beside the mini-USB connector. Figure 04 shows dropmeter in cave during testing phase of the project.

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Contact Address

Mgr. David VARNER, Ph.D.

Kotvrdovice 3

67907 KOTVRDOVICE

Česká republika

E-mail: info@davar.cz

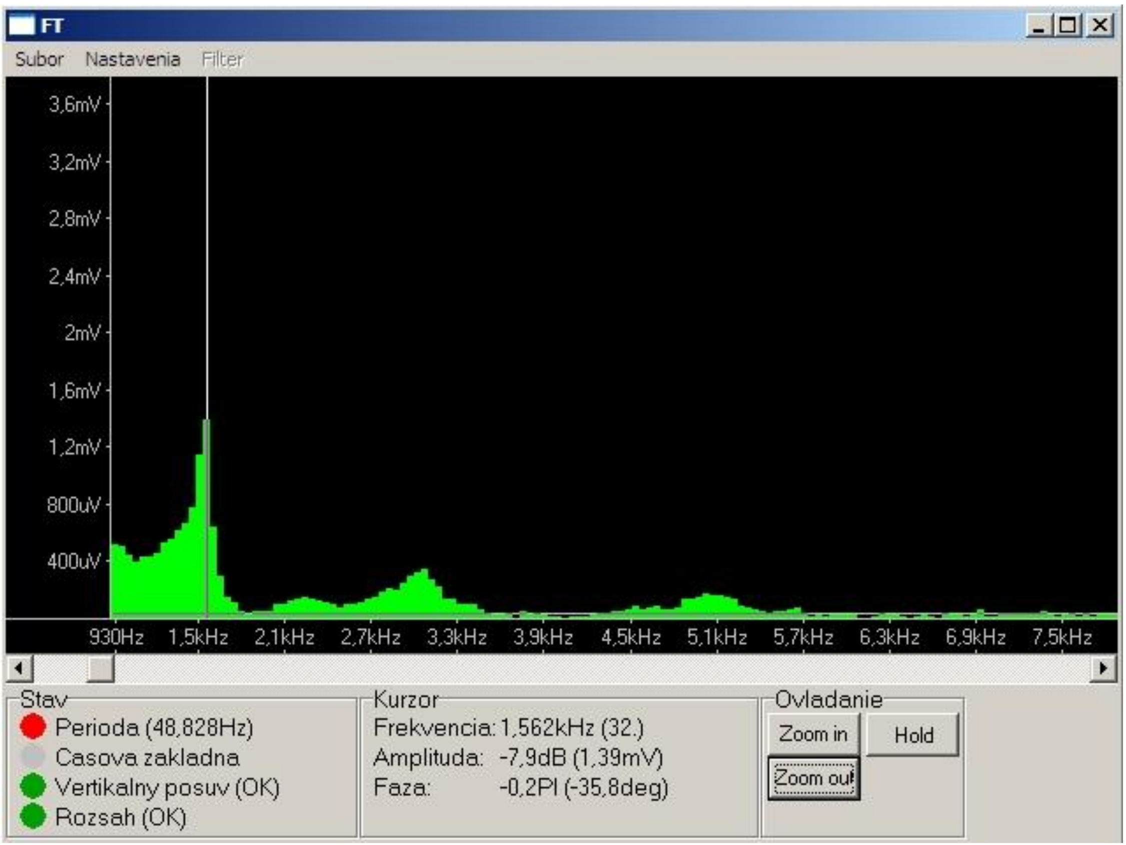

Figure 01: Significant frequency of 1.55 kHz that was used as event trigger.

Figure 02: Overall view of the dropmeter. Photo by D. Varner

Figure 03: Dropmeter application window with Save data tab selected.

Figure 04: Dropmeter in "combat" position in the cave. Note the adjustable tripod and non-horizontal setting of the device. Photo by David VARNER