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Six-degree-of-freedom local seismic records from micro-earthquakes and anthropogenic events

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Full ground motion description, including both translational and rotational components, attracts still more attention in modern seismology. There is a need for portable rotational sensors, easily installed and operated in the field, sensitive enough to provide 6DOF records in a wide range of amplitudes excited not only by strong but also weak motion events. A new prototype of our rotational seismic sensor system (Rotaphone) designed to measure three rotation rate and three ground velocity components is presented. Our method is based on measurements of the differential motions between paired low-frequency geophones attached to a rigid skeleton, the size of which is much smaller than the wavelength of interest. This approach is conditioned by a precise calibration of each paired geophone in the system. A method of our in-situ calibration is explained and demonstrated. The device was thoroughly tested at the Albuquerque Seismological Laboratory, U.S. Geological Survey, with focus on linearity and cross-axis errors. Results of these tests confirm its proper function. The Rotaphone operates in the frequency range 2-40 Hz and its dynamic range is at least 120 dB. It was successfully applied to measure 6DOF ground motions from local shallow micro-earthquakes in the West Bohemia swarm area (Czech Republic), at Hronov-Poříčí fault zone in East Bohemia (Czech Republic), and in the vicinity of the salt-works of Provadia (Bulgaria). It was also used to obtain records from anthropogenic sources (blasts, rockbursts). Three-axial rotation rate records for these types of events are shown and discussed. Their peak amplitudes reach values from 10^{-7} rad/s to 10^{-4} rad/s. To characterize the significance of rotation we define the rotation to translation ratio (RTR) relating peak amplitudes of rotation rate and translational velocity. The RTR factor for different types of local events is discussed in view of its dependence on hypocentral distance, source type and probably on radiation pattern and geological structure along the wavepaths. Thanks to our method of retrieving rotation rates, their records are not contaminated by translational motions. Opposite is not true. Special attention is devoted to the problem of contamination of translational records by rotations. Our approach enables to compensate for this contamination. This procedure is especially important for horizontal translational components that contain a non-negligible contribution from gravity in the case of tilting of the instrument. Possible application of Rotaphones in local seismic networks and seismic prospecting is discussed.