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Enhancing earthquake early warning systems using low-cost MEMS Accelerometer Mini-Array (MAMA)

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Seismic arrays have long been used for seismological research. The coherent signal of a wave field passing through the array can be used to increase signal to noise ratio (SNR), and the differences in arrival times at each of the instruments can be used to derive the directivity of the wave field signal (slowness vector). Using seismic arrays, more robust source and rupture propagation parameters can be obtained. However, seismic arrays are uncommon, and their use is hindered by the prohibitive cost of adding additional sensors to each station of a standard network. Here, we present an array-based approach using mini-arrays of low-cost Microelectromechanical Systems (MEMS) accelerometers. Using the proposed mini-arrays it is possible to estimate reliable hypocentral locations by beam forming (FK-analysis) techniques, and characterize the rupture dimensions for local and regional earthquakes accounting for finite-source effects. We demonstrate these techniques using data acquired from arrays of new low-cost (<$150) higher-quality autonomous Data Acquisition Unit (DAU) we developed and of previously installed dense low-resolution MEMS network.

We use low-resolution 14-bit Quake Catcher Network (QCN) data collected during Rapid Aftershock Mobilization Program (RAMP) in Christchurch, NZ following the M7.1 Darfield earthquake in September 2010 to demonstrate our approach and to solve for the back-azimuth (BAZ) of two events (Mw 4.7 and Mw 5.1) with less than $\pm 10^{\circ}$ error. We present the improved capabilities of the new DAU that includes a high performance analog MEMS accelerometer and demonstrate its usability in calculating BAZ for the 2016-09-13 Mw 3.5 Piedmont event and others.

These higher sensitivity, low-cost accelerometers are deployed as a mini-array around a conventional seismic station, enhancing the network's ability to determine earthquake parameters such as magnitude and location in real-time, specifically at the edge of the network where most operational EEWS a challenged by the sparse station density. This improvement leads to better estimations of the expected shaking at places of interest.