INTEGRATING LOW-COST MEMS ACCELEROMETER MINI-ARRAYS (MAMA) IN EARTHQUAKE EARLY WARNING SYSTEMS

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1. Background

Current operational Earthquake Early Warning Systems (EEWS) acquire data from networks of single seismic stations, and compute source parameters to predict earthquake characteristics. For large events, the point-source assumption leads to an underestimation of magnitude, and use of a single station tends to large uncertainties in the locations of events outside the network.

We propose the use of mini-arrays to improve EEWS. Mini-arrays have the potential to:

(a) Estimate reliable hypocentral locations using beam-forming (FK-analysis) techniques
(b) Characterize the rupture dimensions and account for first-source effects
(c) A key step is to move reliable arrays for large events outside the network.

Previously, the high price of multiple seismometers has made creating arrays cost-prohibitive. We propose setting up mini-arrays associated with conventional seismic stations.

The expected benefits of such an approach include decreasing alert times, improving real-time shaking predictions and mitigating false alarms.

2. Would it work?

In order to test the validity of using array processing techniques with low-cost MEMS, we used recordings from the Quake-Catcher Network low-cost 14-bit MEMS accelerometer array, deployed in Christchurch after the M7.2 Darfield earthquake (Lawrence et al., 2014). We used small sub-arrays of sensors to demonstrate our approach.

YES!

Using 10 stations and 3 stations, with a mini-array dimension of roughly 1.7km by 2.2km and 230m by 270m, and an array-epicenter distances of 13km and 16km, for the M5.1 and M4.7 earthquakes, respectively. As can be seen in Figure 2, the BAZ is stable around conventional seismic stations.

3. Can we do better?

Though the 14-bit QCN sensors are sufficient for the previous example of the M5.1 and M4.7 earthquakes, respectively. As can be seen in Figure 2, the BAZ is stable around conventional seismic stations.

4. How low can we go?

We present here the initial results from the new instrument. We first ran a shake table test using a Gussa TGC accelerometer as a reference (Figure 6). We then place a MAMA device into a QCN MEMS accelerometer. The Probiotic Power Spectral Densities (PPSD) (McNamara and Buland, 2004) are plotted in Figure 7, and compare the power spectral density of near-field and far-field earthquakes (Clifton and Heaton, 2002) and NHNM (Peterson, 1993).

This plot suggests that the MAMA device is expected to detect near-source phenomena. We currently test our MAMA node with QCN 16-bit sensors, and we anticipate the next version to have lower noise levels, and lower detection thresholds.

5. Field Test

We deployed six (6) MAMA nodes on the UC Berkeley campus around the seismic station BK.BKR in January 2013. We used records from a 10-station array (BK.BKR): the minimum distance between two nodes is 500m. The M5.5 Piedmont event occurred on 2016-08-13 and was located ~9.5 km away (Figure 8, left). It was recorded by the MAMA nodes and analyzed as an example of MAMA performance in a realistic scenario. High levels of noise, particularly on the vertical channel, obscured the P-wave arrival. The 5-second wave was detected by the MAMA nodes, and it was possible to calibrate the BAZ for this event within 3 seconds of the P-wave arrival to the central station BK.BKR (Figure 8, right). The observed BAZ is 144º and the calculated BAZ, where relative power values are observed, is 144º-153º.

6. Conclusions

As demonstrated, MAMA can be used to rapidly obtain the BAZ of an event. Combining multiple MAMA may make it possible to reduce false alarm rates. We are currently working on setting up MAMA networks based on just two station-arrays. This would decrease the time needed for point source EEWS to issue an alert. Implementing MAMA back-projection in real-time and incorporating that into EEWS will allow for the better estimation of earthquake magnitudes and shaking intensity distributions, based on first-fault models rather than point-source models.

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References


