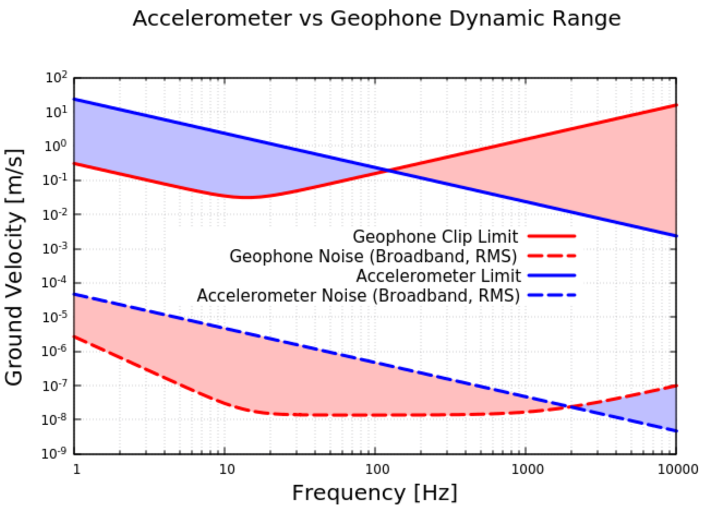
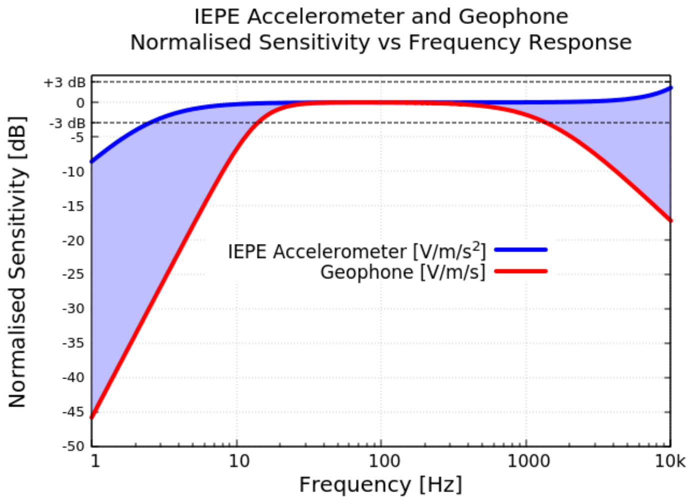
IMS Hybrid and XGM Sensors

Limitations of conventional sensors

For decades, miniature geophones and integrated electronic piezoelectric (IEPE) accelerometers have been the sensors of choice for microseismic monitoring in mines. Which of these sensors to use is not always an obvious decision - there are clear advantages and disadvantages to both. IEPE accelerometers are more sensitive to higher frequencies, and so are better suited to denser arrays monitoring smaller seismic events occurring closer to the sensors. They are also less sensitive to the low frequencies generated by larger events, but saturate more easily on the higher frequencies of even moderately sized events. Geophones have a lower noise floor (and higher dynamic range) over most of their usable bandwidth, but clip more easily due to the large displacements of nearby large events. These concepts are illustrated in the following theoretical graphs, where shaded regions indicate one sensor outperforming the other.





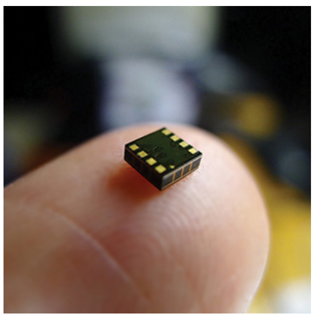
Hybrid Sensors

IMS now offers hybrid sensors where both types of sensor can be included in a single sensor package. Combining the complementary characteristics of geophones and IEPE accelerometers means that better coverage of a wider variety of seismic events is achievable, which ultimately results in higher quality of the seismic event catalogue.

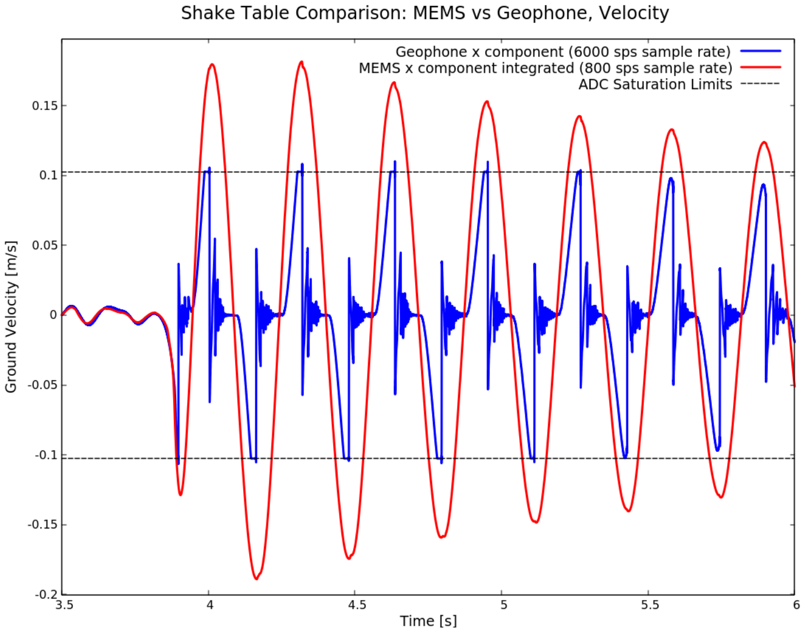
Clipping and Saturation

A common problem with both of these traditional seismic sensors is their limited upper measurement range. Geophones typically clip at ground displacements above a few millimetres, and IEPE accelerometers saturate at ground accelerations above a few tens of *g*'s. Adding to this, when the signal from these sensors is outside of the recorder's analogue-to-digital converter (ADC) voltage range, an additional type of non-linear signal distortion is introduced. All this means that the ground motions of large and/or nearby seismic events cannot be accurately recorded. This is a serious problem because large (often damaging) events are not able to be properly analysed, which makes back-analysis, seismic hazard assessments and other seismological work more difficult.

eXtreme Ground Motion (XGM) Sensors

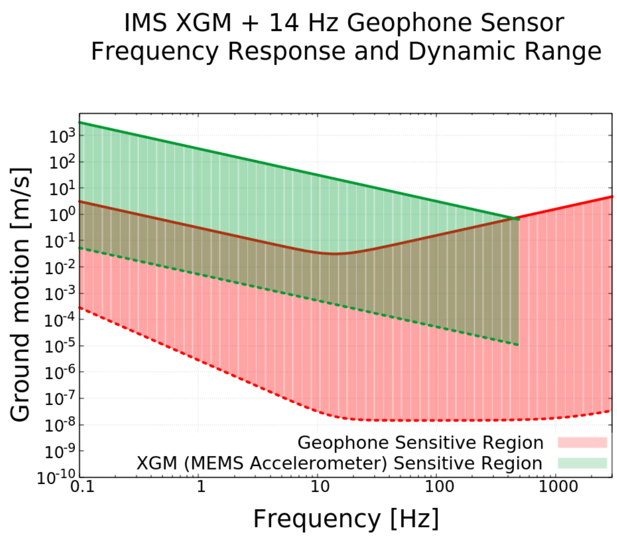


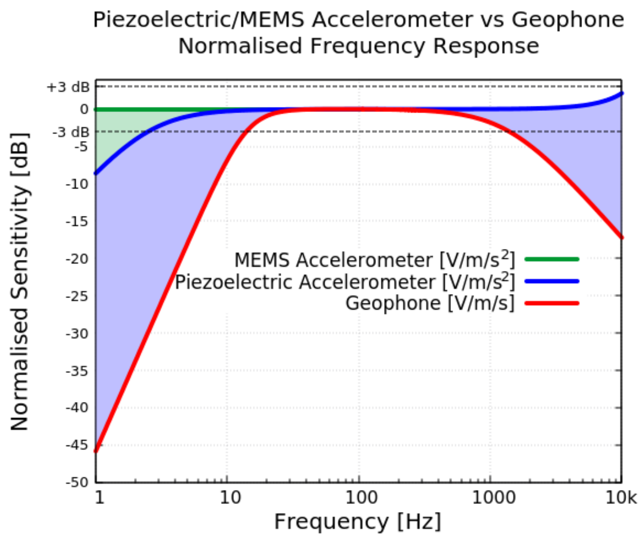
To overcome the limitations of clipping and saturation of conventional sensors and ADCs, IMS have introduced a new range of composite sensors called XGM sensors which rely on MEMS accelerometer technology. MEMS accelerometers are miniature sensors which have higher noise than conventional seismic sensors, but are able to record (with high fidelity) seismic signals with amplitudes that would overwhelm conventional sensors or ADCs.



The figure on the left shows a signal trace recorded on a shake table where a 4.5 Hz geophone (blue trace) displays severe non-linearities due to a combination of ADC saturation and mechanical clipping during strong ground motions. The red trace shows the signal recorded by the MEMS accelerometer embedded inside an XGM sensor, which is clearly more representative of the true ground motion, displaying none of the non-linearities of the conventional geophone sensor.

Every seismic sensor manufactured by IMS, whether geophone, accelerometer or a hybrid combination, now includes XGM sensors. The XGM sensor is able to record the strong ground motions which conventional sensors and ADCs cannot, and because they are sensitive to frequencies down to DC, they will also be capable of recording lower frequency signals. The following figures illustrate these concepts, where shaded regions indicate one sensor outperforming the other. The effective result of the composite XGM sensor is the combination of all shaded regions.





Conclusion

IMS has widened its sensor offering to include hybrid geophone / IEPE accelerometer combinations, and all sensors will now include embedded XGM functionality to enable the recording of high amplitude and/or low frequency seismic signals. Together, these enhancements enable more accurate, efficient and advanced seismological investigations including large event back-analyses and seismic hazard assessments.