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Tracking Helicopters with a Seismic Array

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We observed that the pressure or acoustic wave created by the rotor blades of a helicopter can couple to the ground even at 30 km distance where it creates a signal strong enough to be detected by a seismometer. The signal is harmonic tremor with a fundamental frequency downgliding with the inflection point at e.g. 14 Hz and two equally spaced overtones up to the Nyquist frequency of 50 Hz. No difference in the amplitudes between the fundamental frequency and higher harmonics was observed. Such a signature is a consequence of the regularly repeating pressure pulses generated by the helicopter's rotor blades. The signal was recorded by a seven station broadband array with an aperture of 1.6 km. Our spacing is close enough to record the signal at all stations and far enough to observe traveltime differences.

The separation of the spectral lines corresponds to the time interval between the repeating sources. The highlighted harmonics contain information about the spectral content of the single source as our signal corresponds to the convolution of an infinite comb function and a single pulse. As we see all harmonics and they have the same amplitude up to the Nyquist frequency we can deduce that the frequency content of the single pulse is flat i.e. it is effectively a delta function up to the Nyquist frequency. We perform a detailed spectral and location analysis of the signal, and compare our results with the known information on the helicopter's speed, location, the frequency of the blades rotation and the amount of blades. This analysis is based on the characteristic shape of the curve i.e. speed of the gliding, minimum and maximum fundamental frequency, amplitudes at the inflection points at different stations and traveltimes deduced from the inflection points at different stations.

This observation has an educative value, because the same principle could be used for the analysis of the volcanic harmonic tremor. Harmonic volcanic tremor usually has fundamental frequencies below 10 Hz but frequency downgliding and upgliding up to 30 Hz was observed e.g. on Redoubt volcano. Due to the characteristic shape of the helicopter signal it is nevertheless rather unlikely that this signal is mistaken for volcanic tremor. The helicopter gives us a robust way of testing the method and possible application of the method to volcanic harmonic tremor.