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Frequency power analyses of seismic sources on firn

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A great obstacle for seismic surveys on firn-covered ice masses is the ability of firn to strongly attenuate seismic energy and divert downward ray paths away from the vertical because of the velocity gradient. The standard way to overcome these limitations is the drilling of shotholes about 10-30 m deep. However, drilling of shotholes is a time and energy consuming task. Another possibility is to use vibroseismic sources at the surface and increase the signal-to-noise ratio by repeated stacking. However, compared to explosive charges, vibroseismic signals are bandlimited per se. As a third variant, we investigate the usage of ordered patterns of surface charges consisting of detonation cord. Previous applications of detonation cord only explored their general comparison to bulk explosives when deployed in a linear fashion, i.e. a single line. Our approach extends these results to other geometries, like fan- or comb-shaped patterns. These have two advantages: first, over the pattern area a locally plane wave is generated, limiting the spherical and velocity-gradient induced spreading of energy during propagation; second, the ratio between seismic wave speed of the firn and the detonation cord of typically about 1:5 causes the wave to propagate in an angle downward. When using large offsets like a snow streamer, it is possible to direct the refected energy towards the streamer, depending on offset range and reflector depth. We compare the different source types for several surveys conducted in Antarctica in terms of frequency spectra. Our results show that ordered patterns of detonation cord serve as suitable seismic surface charges, avoiding the need to drill shotholes. Moreover, an example of a short profile with patterned surface charges is presented. The technique can be of advantage for surveys in remote areas, which can only be accessed by aircrafts.