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Noise and vibration suppression in vibratory pile driving using locally-resonant metamaterials

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The increasing demand for renewable energy sources is driving a significant rise in the adoption of offshore wind energy. Offshore wind turbines are typically supported by large foundation piles driven into the seabed. The primary method of installation is by hydraulic impact hammers. However, this method generates excessive underwater noise among other drawbacks. Consequently, alternative techniques are being explored by both researchers and industry. One promising alternative is vibratory driving, which theoretically produces less underwater noise compared to impact driving. Nevertheless, there remains a substantial amount of energy transmitted into the water column, particularly from the higher harmonics of the driving frequency. While energy at the fundamental frequency is essential for efficient driving, energy associated with higher harmonics does not contribute to this efficiency and can significantly increase radiated underwater noise. To address this issue, this study proposes a mitigation strategy to block energy transfer at super-harmonic frequencies in the pile-water-soil system. To selectively target these frequencies without affecting the fundamental one, a mitigation approach utilizing locally-resonant metamaterials is proposed. This involves integrating a transition piece between the vibratory hammer and the pile, that incorporates periodically inserted multiple-degrees-of-freedom systems. By manipulating the natural frequencies of these periodic inclusions, the transition piece forms band-gaps at the relevant super-harmonics. Initial findings indicate that this design has the potential to effectively mitigate noise and vibration at targeted frequencies. Nonetheless, further investigations employing more sophisticated models are necessary to validate these outcomes.