Investigation of Ultrasonic Transducer Response

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Introduction

- Ultrasonic transducers are used across many disciplines (e.g. geophysics, medicine, and civil engineering) to characterize the nonlinear elastic properties of complex solids.
- Shear wave (S-wave) transducers generate waves that are transverse in nature, meaning the particles of the medium move perpendicular to the direction of wave propagation.
- Previous research in our group used S-wave contact transducers to assess nonlinear wave interactions in rocks for geophysical applications.[1]

Methods

We employ a two-transducer pulse transmission technique.[2,3] This technique uses two transducers aligned on opposite ends of the sample. One transducer acts as the source, and the other acts as the receiver. The source transducer produces an ultrasonic elastic wave which propagates through the sample and is then sensed by the receiver on the other end.

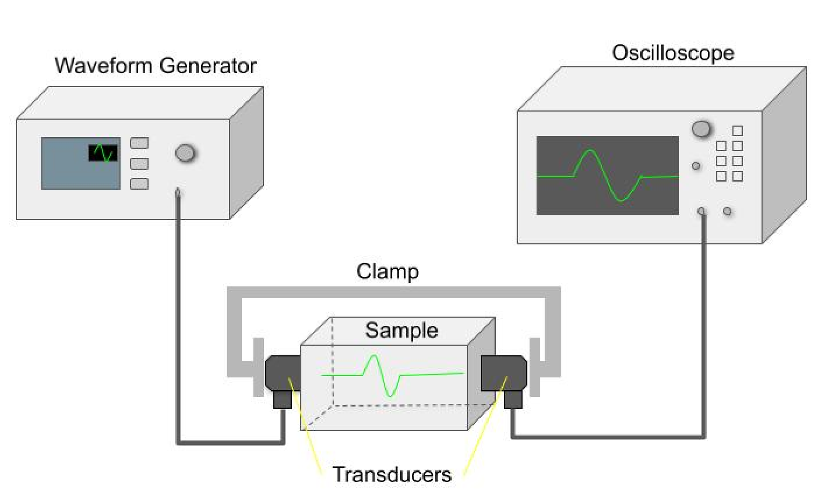

Fig. 1 Experimental setup.

Key Finding

When coupled to a sample, shear wave transducers generate a one-cycle coupling signature whose frequency is independent of the input parameters.

Results & Discussions

No sample (baseline response)

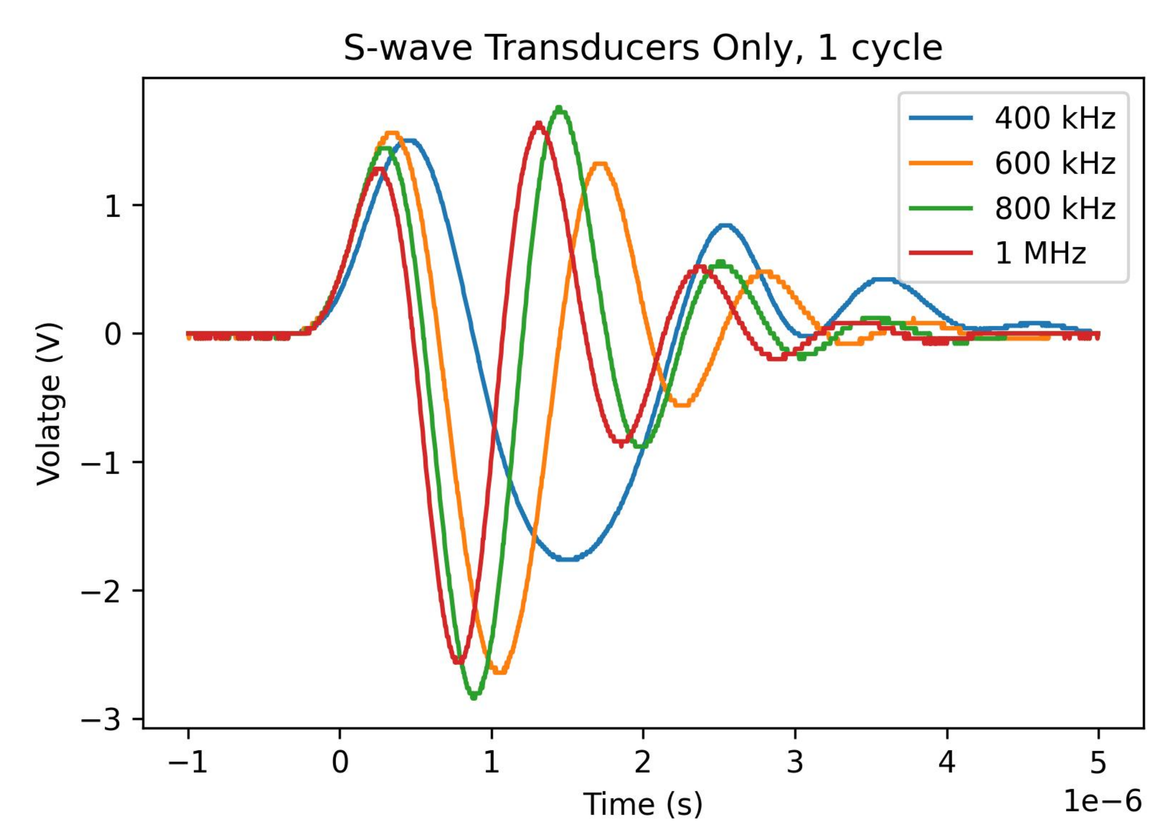

Fig. 2 To establish our S-transducers' ability to generate and sense pulses with different frequencies, we begin by coupling two S-transducers together without introducing a solid material between the pair and transmitting a series of single-cycle pulses over the range of 400 kHz to 1 MHz. As expected, each pulse possesses a different period in accordance with its input frequency (see legend). This data acts as a baseline for what our ultrasonic pulses should look like when they are both generated and sensed by S-transducers.

Cement sample (frequency-independent response)

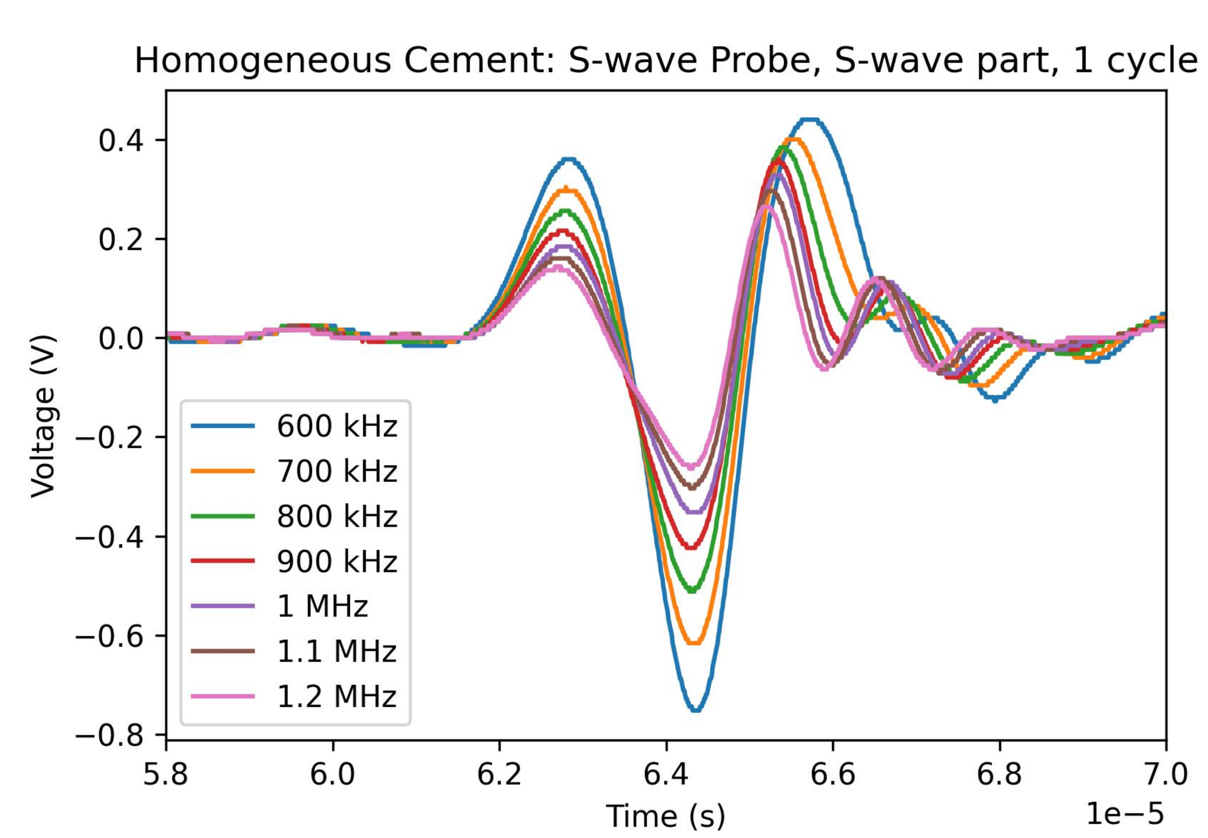

Fig. 3 We introduce a block of homogeneous cement between the two S-transducers and transmit a series of single-cycle pulses over the range of 600 kHz to 1.2 MHz. Unexpectedly, each pulse possesses approximately the same period. Hence, the frequencies of these pulses are not in accordance with their respective input frequencies (see legend). Rather, the first cycle of each pulse is contaminated by a **coupling signature**, whose frequency is independent from the input parameters.

Conclusions

- When coupled to a sample, S-wave transducers generate a coupling signature whose frequency is independent of the frequency set on the generator.
- When a pulse consists of multiple cycles, the first cycle of the pulse is contaminated by the coupling signature.
- S-wave transducers are not a viable option for measuring the relationship between probe frequency and nonlinear elasticity.

Future Work

- Use P-wave transducers to investigate the relationship between elastic wave frequency and nonlinear elasticity.
- Best practices for future work should monitor waveforms passing through the sample, not just input waveforms.

References

[1] J. E. Newman *Dependence of elastic nonlinearity on aligned inhomogeneities*, Thesis, Memorial University of Newfoundland, 2021.

[2] F. Birch *Journal of Geophysical Research* **65,** 1083–1102 (1960).

[3] A. Yurikov, N. Nourifard, M. Pervukhina, M. Lebedev *The Leading Edge* **38,** 392–399 (2019).

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