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Non-collinear wave mixing with Phased Array transducers

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Motivation

Drinking water supply mains are degrading over time and the current state of a particular piece of pipeline is mostly unknown. Often, assets in good condition are replaced prematurely, resulting in increased cost and material usage whereas other assets fail before expectation time. Inspection of drinking water supply mains is important in order to determine the current state of the assets for its effective replacement or maintenance.

Non-destructive testing (NDT) is a common method of inspection of water mains. However, there is much more to improve. Polymers like PVC are very difficult to assess using current NDT methods, however, a new technique has been developed in the Wetsus Smart Water Grids research project *Development of Inline Water Mains Inspection Technology*, which makes this possible. This technique of non-collinear wave mixing has been verified with single element transducers as seen in Figure 1. However, extensive mechanical alignment is needed to obtain promising results [1-4]. The use of actuator and receiver arrays enables steering and focusing of the beam at desired angles and directions, which eliminates the need for its mechanical alignment since this can now be done with signal processing. In this way, the method can be applied in water mains with varying diameter and composition.

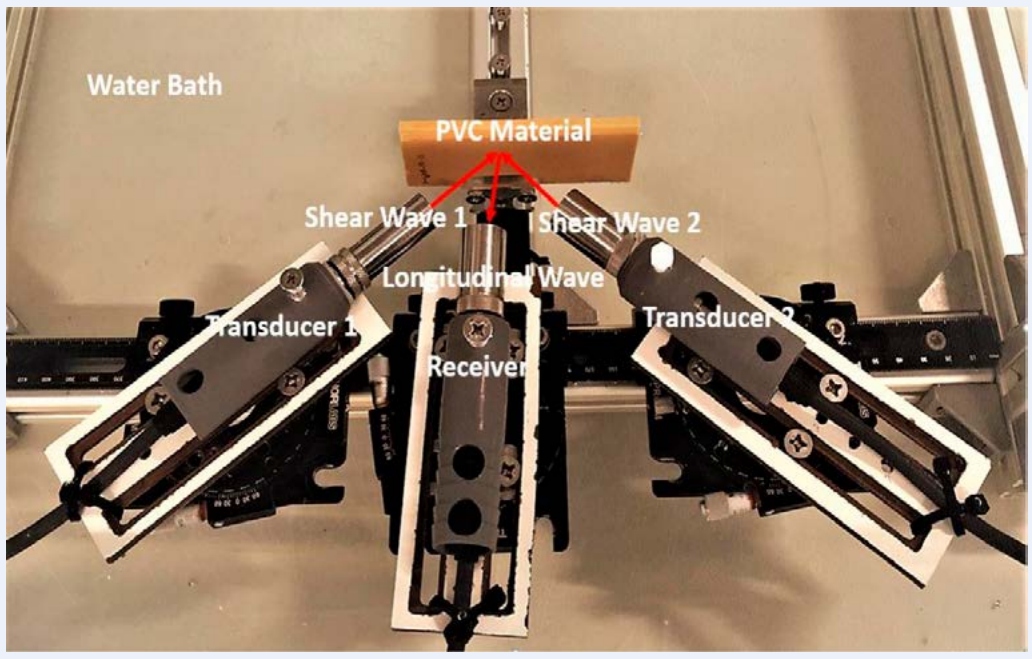

Figure.1 Non-collinear wave mixing configuration where two broadband transducers transmit shear pump waves into a PVC material, in which they interact to generate a longitudinal wave which is recorded by a receiver.

Technological and Scientific Challenges

The challenge lies in 1) investigation of array techniques which are able to generate a well-defined acoustic intensity at a definite area in the material to be investigated, 2) proper alignment of the phased array sensors with respect to the surface of the material, 3) effective detection of the resulting mixed signals 4) storage and handling of a large amount of data, 5) visualization of recorded data and 6) determination of the relative material state from the recorded mixed signal.

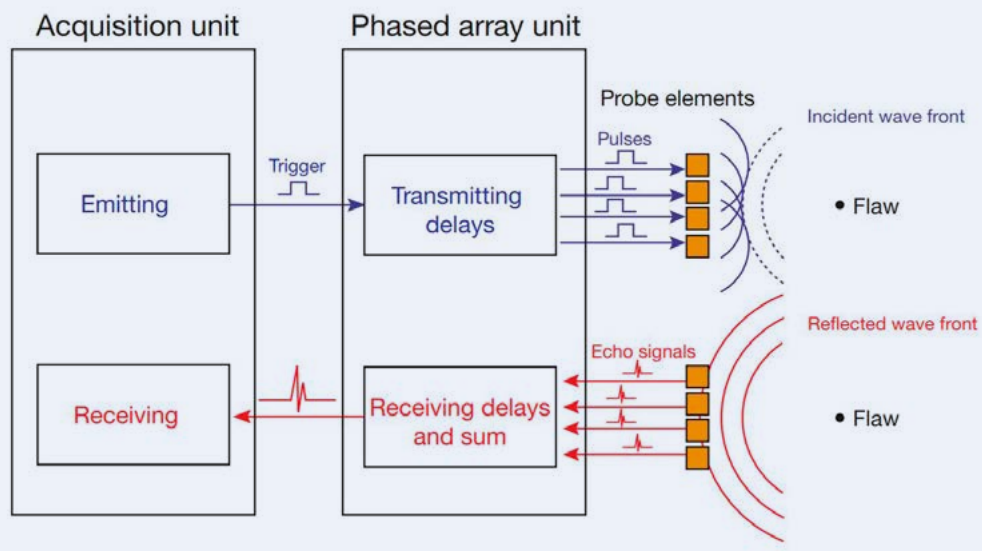

Figure.2 Multiple piezocomposite elements are pulsed at slightly different times to generate a beam. Precise control of the delays between the elements generate beams with various angles, focal distances and focal spot sizes. The echo from the desired focal point hits the elements with a computable time shift. The signals received at each element are time-shifted before being summed up. The resulting sum represents the response from the desired focal point [5].

Research Goals

The possible array transducer configurations must be studied, keeping in mind their specific application in water mains. This will be done by acoustic wave propagation modelling, phased array modelling, testing the model with a lab scale set up, field verification of the model, excitation mimicking multiple number of transducers, reception of the resulting signal with the same transducer array and analyzing the received signal to determine material properties.

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[4] Delgadillo, H. H., Loendersloot, R., Akkerman, R., & Yntema, D. (2016). Development of an inline water mains inspection tech nology. Paper presented at the IEEE International Ultrasonics Symposium, IUS, 2016-November doi:10.1109/ULTSYM.2016.7728471.
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