

## Ultrasonic Phased Array for Investigations of Concrete Components

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### Abstract

This paper describes an innovation of a phased array using dry contact probes to test concrete components. Based on preceding work on pressure waves, a low-frequency ultrasonic phased array consisting of shear wave probes is used in the experiments. This configuration allows the variation and control of the sound field directivity during the measurement. The measurements are carried out on a concrete test block using a scanning laservibrometer and a scanner system in transmission mode. The laboratory measurements are compared to theoretical calculations to investigate the influence of the probes shape and dimension on the resulting sound field patterns. The comparison of the modelling and the measurements demonstrates the suitability of the point source synthesis as a tool for the optimization of probe array designs. Methods of coded are used to improve the signal to noise ratio.

**Keywords:** Ultrasonic, phased array, concrete, point source synthesis

### 1. Introduction

In the past years, low-frequency ultrasonic probes with dry point contact have been successfully used for non-destructive testing in civil engineering [1]. Probe arrays of any size and shape can be designed using shear wave probes in order to get a higher signal amplitude and a more directed sound beam [2]. It is important to investigate the ultrasonic field characteristics of the probe array in order to find the optimum array design for phased array application. Modelling based on the point source synthesis is applied for the array optimization. Controlled transmission signals methods are applied in order to improve the signal to noise ratio.

### 2. Design of ultrasonic phased array using dry point contact probes

Figure 1 shows schematically two possibilities controlling the emitted sound field of a linear array. By setting different transmission pulse delay times for each emitter element, the ultrasonic beam can be deflected and/or focused in the measurement object. The ultrasonic field can be controlled by generation of transmitted pulses with mutual delays which are based on the transit times to focus on a desired target in the measurement object.

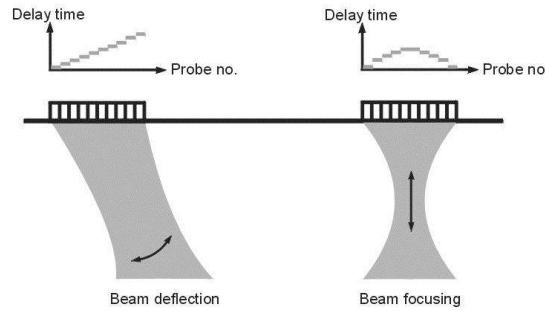


Figure 1. Sound beam control using a phased array (adapted from [2])

Prior to the experimental study, the radiation patterns of the probe array are investigated by point source synthesis [3]. For this reason, modelling results are compared to measurements of a concrete half-sphere with a radius of  $r = 325$  mm. Figure 2 shows the calculated and measured radiation pattern of seven shear wave probes with a distance of 20 mm between each other. The radiation patterns are based on emitted waves which are polarized perpendicular to the plane of incidence and array axis.

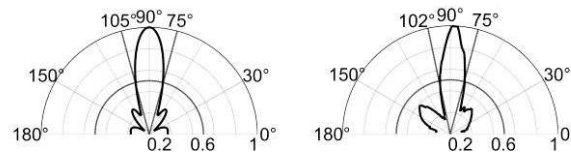


Figure 2. Calculated (left) and measured (right) radiation pattern of seven probes, polarization is oriented vertical to the plane of incidence, probe distance is 20 mm (adapted from [2])

Both, the results of the simulation and the measurement clearly show a more concentrated ultrasonic beam. As it can be seen, the side lobes can be suppressed by choosing an optimal proportion between the distance of probes and the ultrasonic wavelength. The comparison of the simulation and the measurements demonstrates the suitability of the point source synthesis as a tool for optimizing of probe array designs. Below, modelling results show the radiation pattern of nine probes with a distance of 20 mm between each other. As it can be seen, the side lobes can be successful suppressed.

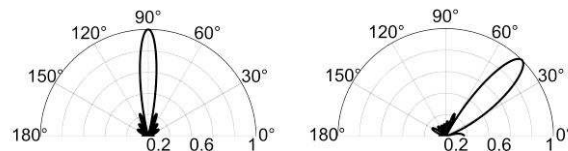


Figure 3. Calculated radiation pattern of nine probes for beam deflection of 0 and 45 degree, polarization is oriented vertical to the plane of incidence, probe separation is 20 mm

An illustrative method to demonstrate the function of the phased array is the visualization of the wave propagation. Figure 4 shows a calculated and measured snapshot of the wave propagation during a sound beam focusing. It demonstrates a curved wave front by using the phased array technique focusing on a point in the depth of 150 mm.

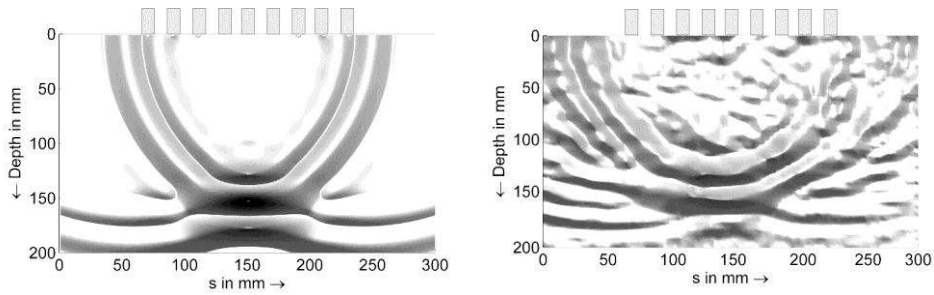


Figure 4. Visualization of wave field generated with a nine probe phased array operated in focusing-mode, left: calculation, right: measurement (adapted from [2])

Controlled transmission signals are applied in order to improve the signal to noise ratio.

### 3. Coded transmission in ultrasonic non-destructive testing

The usage of phase coded excitation signals and corresponding matched filters (correlators) enables the suppression of inherent sound-scattering in reception patterns, which leads to higher signal-to-noise ratios. Figure 5 illustrates the functional principle on the bases of Golay coding with a RC2-pulse carrier signal.

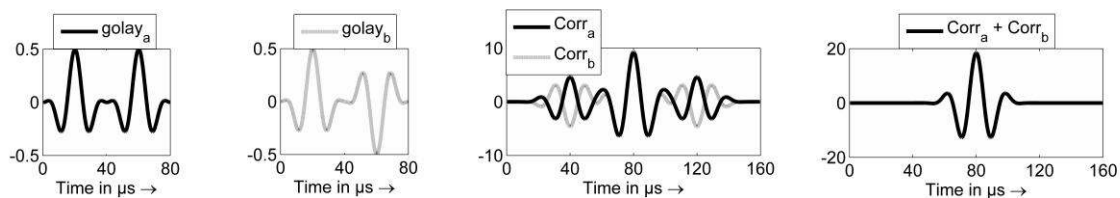
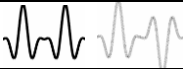



Figure 5. Complementary Golay code pair with a RC2-pulse carrier signal

The measurements are performed with transversal wave transducers and a wavelength of 40 mm in concrete to ensure a good comparability. Furthermore varied time delays between the sub pulses are investigated. After correlating the echograms with their corresponding excitation signals and a further addition in case of Golay coding the resulting signal-to-noise ratios are calculated. The following table displays the achieved result.

**Table 1. Improving of the signal to noise ratio**

|                   | Excitation signal   | SNR  |
|-------------------|---|------|
| Golay             |  | 16,4 |
| Rectangular pulse |  | 11,1 |

Pulse compression by the use of Golay coding results in a better signal-to-noise ratio than the use of a rectangular pulse.

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