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Golay-Based Total Focusing Method Using a High-Frequency, Lead-Free, Flexible Ultrasonic Array to Improve Industrial Inspections

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High frequency (>15 MHz) ultrasound arrays have attracted considerable interest in recent years due to their ability to provide images with enhanced spatial resolution, offering higher sensitivity to smaller defects in materials and structures. Defects can be detected at earlier growth stages as compared to lower frequency counterparts. Conversely, high-frequency sound waves have limited penetration depth that can hinder the inspection of thicker components. Moreover, research into lead-free alternatives to lead zirconate titanate (PZT) is prominent due to the European Union's Restriction of Hazardous Substances (RoHS) regulation. Achieving optimal ultrasound imaging with lead-free materials remains a persistent challenge, given the importance of transducer sensitivity. Here, an advanced approach combining a high-frequency, lead-free, flexible ultrasonic array and Golay-coded excitation to address the limitation in penetration depth in ultrasound imaging, particularly of samples with non-planar surface geometries, is presented.

This study employed a commercial 20 MHz 64 element 1 mm pitch lead-free flexible linear ultrasonic array, developed by Novosound Ltd, using Golay-coded excitation to improve the penetration depth and exploit the flexibility for operation on both planar and non-planar components. Golay complementary sequences were designed and employed to excite the array. Pulse compression was realised through the application of a matched filter.

A signal-to-noise ratio (SNR) improvement verification study was conducted with the array deployed on a 20 mm thick planar aluminium sample. As anticipated, an increase in SNR was observed as the length of the Golay codes increased, matching the theoretical 3 dB improvement between successive length doubling. Furthermore, the appropriate Golay code length is contingent on the specific demands of the application with respect to acceptable SNR and minimisation of the dead zone to improve near surface inspection capability. The array offers the versatility to adapt to complex surface profiles. A curved test specimen with known defects was next explored. Total focusing method (TFM) images of the sample for both pulse and Golay excitations were obtained and compared. The Golay-based TFM outperformed the standard pulse-based TFM, resulting in an improved imaging penetration depth.

The proposed approach, which integrates a RoHS-compliant, flexible array with Golay-coded excitation, has the potential to improve the quality of industrial inspections in terms of efficiency, accuracy, and reliability.