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Focused Ultrasonic Beam Behavior at a Stress-Free Boundary and Applicability for Measuring Nonlinearity Parameter in a Reflection Mode

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Measurements of the acoustic nonlinearity parameter β are frequently made for early detection of damage in various materials. The practical implementation of the measurement technique has been limited to the through-transmission setup for determining the nonlinearity parameter of the second harmonic wave. For the purpose of practical applications, a pulse-echo measurement technique is more desirable which enables the single-side access of test components. The issue with using the second harmonic wave reflected from the stress-free interface is that such a boundary destructively alters the nonlinear generation process and consequently makes it difficult to obtain the reliable results of β.

In this work, we employ a focused beam theory to modify the phase reversal at the stress-free boundary, and consequently enhance the second harmonic generation during its back-propagation toward the initial source position. We first confirm this concept through experiment by using a spherically focused beam at the water-air interface, and measuring the reflected second harmonic and comparing with a planar wave reflected from the same stress-free or a rigid boundary. In order to test the feasibility of this idea for measuring the nonlinearity parameter of solids in a reflection mode, an array transducer beam is modeled for focusing at and reflection from a stress-free boundary. A nonlinearity parameter expression is then defined together with diffraction and attenuation corrections.

Acknowledgements:

This work was supported by the Basic Science Research Program through the National Research Foundation of Korea (Grant No. 2013-M2A2A9043241), and by the National Natural Science Foundation of China (Grant Nos. 61271356, 51575541).