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Simultaneous Sum-Frequency and Vibro-Acoustography Imaging for Nondestructive Evaluation (NDE) and Testing (NDT) Applications

Farid Mitri[a], Glauber Silva[b], James Greenleaf[a] and Mostafa Fatemi[a]
[a]Dep. of Physiology and Biomed. Eng., Mayo Clinic College of Medicine, 200 First Street SW, Rochester, MN 55905, USA
[b]Instituto Nacional de Matematica Pura e Aplicada, 22460 Rio de Janeiro, Brazil

High-resolution ultrasound imaging systems for inspection of defects and flaws in materials are of great demand in many industries. Among these systems, Vibro-acoustography (VA) has shown excellent capabilities as a non-contact method for non-destructive high-resolution imaging applications. This method consists of mixing two confocal ultrasound beams, slightly shifted in frequency, to produce an acoustic emission field at the difference frequency of the primary incident ultrasound beams. In addition to the difference frequency signal, there exists another signal at the sum frequency, formed in the intersection region of the two primary beams. The goal of this study is to investigate the formation of high-resolution images using the sum frequency of ultrasound waves in VA while concurrently forming the conventional difference-frequency VA image, thereby increasing the amount of information acquired during a single scan. A theoretical model describing the sum frequency wave propagation, including beam forming and image formation in the confocal configuration is developed and verified experimentally. Moreover, sample experiments are performed on a flawed fiber-reinforced ceramic composite plate. Images at both the difference and sum frequencies are compared and discussed. Results show that the sum frequency image produces a high-resolution C-scan of the plate by which the flaws and structural details of the plate can be detected.