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The Plane Wave Expansion Technique to describe diffraction of sound

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ABSTRACT

The plane wave expansion, first developed by Lord Rayleigh and essentially based on a Fourier series, is described in detail. An overview is presented of the history of the (re)introduction of this technique in acoustics in the 1980's and its reappearance to solve current problems in nondestructive testing of materials and interaction of sound with phononic crystals. For instance, one significant difference between periodic surfaces and smooth surfaces is that certain unique features occur in the reflection and transmission spectra obtained from periodic surfaces that do not appear in the spectra resulting from smooth surfaces. In particular, sharp discontinuities occur at certain frequencies in the spectra obtained from periodic surfaces. These discontinuities were first observed experimentally in ultrasonics by Jungman et al. in the early 1980's and were interpreted as being due to mode conversion between bulk and surface waves along the surface. They were named Wood anomalies in reference to the analogous optical phenomena introduced by Wood. Although the classical grating equation successfully described the relationship between surface periodicity, surface wave velocities, and frequency positions of the anomalies, no other theoretical treatment was available at the time that could predict the occurrence of these anomalies in the spectra. It was soon discovered by Claeys and Leroy that the Plane Wave Expansion technique for modeling diffraction on periodic surfaces could accurately predict ultrasonic reflection and transmission spectra obtained from periodic liquid-solid interfaces. Anomalies in the spectra were attributed to the generation of Rayleigh or Scholte-Stoneley waves as a result of diffraction and mode conversion on the surface. More recently a more exotic physical phenomenon, namely a backward beam displacement when sound interacts with the periodically corrugated surface, was explained by means of a combined theory of Plane Wave Expansion and inhomogeneous wave theory. Perhaps the greatest advantage of the Plane Wave Expansion technique is its straightforward applicability and its relatively simple ability to produce amplitude and phase information of diffraction orders.