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基于耦合反射/透射系数单程波传播算子的地震波模拟研究

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摘要 单程波近似实际上是一种多次前向散射和单次后向散射近似.利用单程波近似来描述波传播可以极大地节省地震数值模拟的计算时间和内存，实现地震波长距离传播模拟和三维地震模拟快速计算.本文基于单程波近似和波动积分方程的分离变量逼近,从广义Lippmann-Schwinger波动积分方程推导出耦合反射/透射系数的单程波传播算子.该算子由两部分构成：分离变量Fourier单程波传播算子和薄板间的反射/透射系数表达.前者将常规的Fourier分裂步单程波传播算子(SSF)推广适应横向强速度变化介质和大角度传播波场.后者是利用垂直波数来表示反射/透射系数，自然耦合到波场传播的计算过程中，其为地质界面倾角的隐式表达，精确描述振幅随入射角的变化，能适应任意复杂的模型.通过两个数值算例和一个实际地质模型的计算，本文将该方法和边界元法进行了比较，结果表明：在算例给出的介质横向速度变化情况下，本文提出的方法在相位和振幅方面与全波数值方法基本吻合.

关键词 单程波动积分方程 分离变量逼近 单程波近似 反射/透射系数 地震模拟
分类号 P315

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One-way propagators coupled with reflection/transmission coefficients for seismogram synthesis in complex media

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Abstract The one-way and one-return approximation is a multiple-forescattering-single-backscattering (MFSB) approximation. Compared with the full-waveform numerical methods, one-way approximation leads to a great saving of computing time and memory, which makes it possible to modelling wave propagation in long distances. In this article, we combine both the one-return and separation-of-variables approximations to develop a new one-way propagator coupled with reflection/transmission (R/T) coefficients for seismogram synthesis in complex media. The method is derived from establishing simultaneous generalized Lippmann-Schwinger equations in two adjoining heterogeneous layers followed by the separation-of-variables and one-return approximations. The resulting one-way propagator consists of two parts: the separation-of-variables screen propagator and the R/T operators that account for amplitude variations with incident angles across interfaces. The separation-of-variables screen propagator for one-way wave propagation accounts for wide angles in large-contrast media. The R/T coefficients are the implicit function of dip angle of geology subsurface, whose calculation is coupled with one-way propagation simulation in a natural manner. We benchmark the presented method against the full-waveform boundary element (BE) method for two numerical examples and a real geology structure, which shows that the presented method simulate the reflected waves well in travel time, amplitude, and waveform for various velocity contrasts across interfaces.

Key words One-way integral equation; Separation-of-variables approximations; One-return approximations; Reflection/transmission coefficients; Seismic modelling

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