Chapter 1. Introduction

A theory which properly deals with diffracted multiple reflections is of particular interest in exploration seismology. Although the geometrical component along reflection paths is admittedly large, the often irregular nature of the near-surface crust being explored creates a situation where a description by waves is both desirable and necessary. The presence of multiple reflected waves, as opposed to rays, is often noted on the seismic records by characteristic diffraction hyperbolas and focused regions. More often the evidence of wave phenomena is more subtle or complicated.

In a practical sense, multiple reflections are regarded as a problem. They tend to impede the task of even the experienced interpreter in deducing information from the reflection data. Directly, multiples often mask and confuse the mapping of true reflecting horizons and, indirectly, introduce spurious results in the analysis of subsurface velocities. Thus, it becomes desirable to model and eliminate multiple reflections. In the literature there have appeared many methods for modelling and eliminating the undesirable effects of multiple reflections [see for example, Goupillaud (1961), Trorey (1962), Sherwood and Trorey (1965), Treitel and Robinson (1966), Claerbout (1968), Peacock and Treitel (1969)]. These methods have all been based on one-dimensional or layered media models of the earth.

The principle aim of this thesis is two-fold: to first develop a theory which includes the phenomena of multiple reflected waves in a two-dimensional earth; and secondly, to develop a theory for directly predicting and extinguishing diffracted multiple reflections. The former will be referred to as the forward problem and the latter the inverse problem. Much of the discussion and many of the numerical examples will relate to multiples encountered in marine exploration. This is where the problem is often most severe. Additionally, we concentrate on describing situations in moderate-to-deep water. However, the ideas and techniques developed are equally valid for land exploration and shallow water marine data.

In the following chapter we begin with a one-dimensional model and develop an interesting approach to modelling and eliminating a large, important class of multiples. Several of the assumptions and techniques developed here will be carried over to the subsequent two-dimensional theory.

In chapter 3, we start with the two-dimensional scalar wave equation and derive subsidiary equations for the one-way propagation of up and downgoing waves. With some simplifying assumptions, equations for propagating these waves separately in velocity inhomogeneous media are obtained. Expressing these equations in terms of finite difference approximations, a general numerical modelling algorithm is derived. Use of the algorithm is illustrated with several examples of synthetic 2-D seismograms.

Chapter 4 relates to the two-dimensional inversion of multiple reflected waves. The inverse problem of reflector mapping is initially defined in terms of previous assumptions and equations. Paying particular attention to causal directions of propagation in time and space, two fundamental reflector mapping principles are related to the inverse problem of both migrating the primary reflectors and removing multiple reflections. On the basis of these principles and the ability to downward continue the surface recordings, a consistent method of imaging reflectors, estimating reflection coefficients and extinguishing diffracted multiple reflections is obtained. Use of the inverse algorithm is demonstrated on synthetic data for a variety of models. Finally the proposed inversion technique is related to expected requirements for field data necessary for a practical application.