G009 EXTENDING THE MACRO MODEL BY INCORPORATING FINE-LAYERING PROPAGATION EFFECTS

R.E. SLOT and C.P.A. WAPENAAR
Delft University of Technology, Lab. of Seismics and Acoustics, PO Box 5046, 2600 GA Delft, The Netherlands

Introduction

In seismic migration the elimination of propagation effects from the seismic data plays a major role. A wave propagating through the earth will encounter 'large contrast' boundaries which are separated by sequences of thin layers with smaller contrasts. Usually the propagation effects are quantified by a *macro model*, which accounts for the large contrast boundaries but suffices with the *average* velocities (and densities) of the thin-layering between these boundaries. Hence, the *angle-dependent* dispersion effects due to internal multiple scattering in finely layered media, which have been studied extensively (O'Doherty and Anstey, 1971; Burridge and Chang, 1989; Herrmann and Wapenaar, 1992), are neglected in a macro model. We investigate the possibility of replacing a finely layered medium by a *homogeneous*, *anisotropic*, 'effective' medium with *anelastic losses*, thus mimicking the angle-dependent dispersion effects, and allowing for these effects to be incorporated in a 2-D or 3-D *extended macro model* for true amplitude migration.

Defining the anisotropic effective medium parameters

The transmission response of a finely layered medium between depth levels z_0 and z_m can be written in the rayparameter-frequency (p, ω) domain as

$$\tilde{W}_g^+(z_m, z_0; p, \omega) = \tilde{W}_p^+(z_m, z_0; p, \omega)\tilde{C}(z_m, z_0; p, \omega), \tag{1}$$

where $\tilde{W}_g^+$ is the *generalized primary* extrapolation operator and

$$\tilde{W}_p^+(z_m, z_0; p, \omega) = \exp\{-j\omega \cos\phi_{\text{eff}} < \frac{1}{c} > \Delta z\}, \tag{2}$$

is the extrapolation operator for the *primary* wave, in which

$$\cos\phi_{\text{eff}} = \sqrt{1 - c_{\text{eff}}^2 p^2}, \tag{3}$$

with $c_{\text{eff}}^2 = < c > / < \frac{1}{c} >$ and $\Delta z = z_m - z_0$.

$$\tilde{C}(z_m, z_0; p, \omega) = \exp\{-A(\omega \cos\phi_{\text{eff}})(\cos < \phi >)^{-n} \Delta z\} \tag{4}$$

is a *correction operator* that accounts for the angle-dependent dispersion effects, in which $A(\omega)$ is the fourier transform of the causal part of the auto-covariance of the reflectivity function (modified after O'Doherty and Anstey, 1971), and n is either 0 or 4 for respectively density or velocity contrasts (for simplicity, we refrain from considering the case of both density as well as velocity contrasts in this abstract). Assuming a finely layered medium is a realization of a fractal Brownian motion process, we can use the scaling property $A(\omega \cos\phi_{\text{eff}}) = A(\omega)(\cos\phi_{\text{eff}})^\alpha$ (Herrmann, 1991), where α is the slope of the power spectrum.

The response of a homogeneous anisotropic medium with anelastic losses can be written as

$$\tilde{W}^+(z_m, z_0; p, \omega) = \exp\{-j\frac{\omega}{c_V}\sqrt{1 - p^2 c_H^2}\Delta z\}, \tag{5}$$

with frequency dependent vertical and horizontal phase velocities c_V and c_H.
Expanding the exponential terms in both equations (1) and (5) around $p = 0$ (taking $\phi_{\text{eff}} =< \phi >$) and equating the resulting coefficients of p^0 and p^2, c_V and c_H can simply be expressed in terms of the fine-layering medium parameters,

$$\text{coefficients of } p^0: \quad \frac{1}{c_V} = \left(< \frac{1}{c} > + \frac{A(\omega)}{j\omega}\right) \qquad \text{coefficients of } p^2: \quad \frac{c_H^2}{c_V} =< c > \left(1 + \frac{\alpha - n}{< \frac{1}{c} >}\frac{A(\omega)}{j\omega}\right). \tag{6}$$

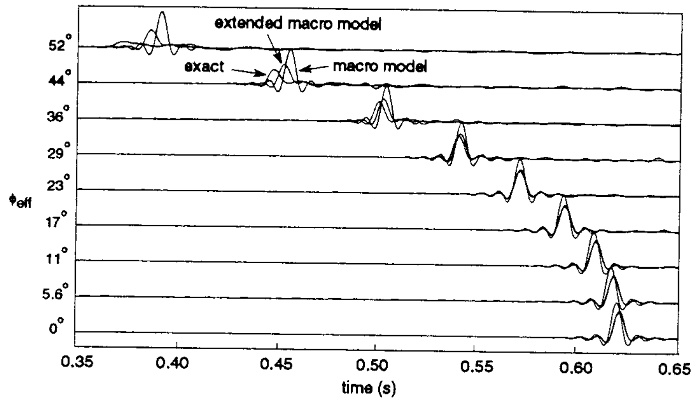

Figure 1: Transmission responses, *exact* versus *macro model* versus *extended macro model* for different angles

These elliptical anisotropic velocities, when used in equation (5), mimic the propagation effects of a finely layered medium and thus define an *effective* homogeneous, anisotropic medium with losses. For a more detailed derivation, see Wapenaar and Slot (1994).

Examples and conclusions

The modeled medium consisted of 15000 layers of 10 cm each, statistically described by fractal Brownian motion, with average velocity $< c >$ of 2500 m/s and a standard deviation of 413 m/s. The density was taken constant.

In Figures (1) and (2) the *exact* (numerically modeled) transmission response is compared with the response modeled by the *extended macro model* (as described above), and with the response modeled by the (standard) *macro model*. The extrapolation operator of the macro model uses only the average slowness of the stack of thin layers (such that for $p = 0$, it is identical with equation (2)). The improvement on the (rather poor) macro model solution is quite substantial, certainly for angles below 30 degrees. For higher angles the *extended* macro model becomes inaccurate due to the expansion around $p = 0$, and due to tunneling effects which are not accounted for, but it still matches the exact solution much better than does the macro model. If, as in equation (6), we also equate the coefficients of p^4, we obtain three anisotropic parameters, which then describe a more general T.I. *effective* medium. Attenuation effects are again improved (accurate up to around 45 degrees) and, although arrival-time effects require a more elaborate interpretation, these also clearly show improvement.

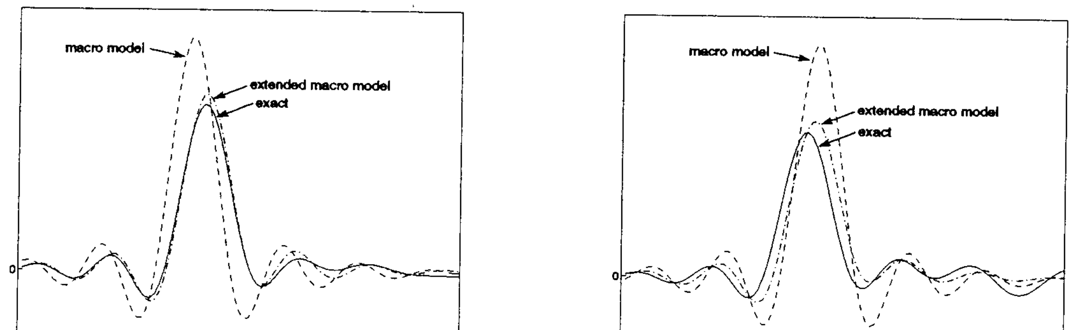

Figure 2: Transmission responses, (a) for *normal incidence* and (b) for incidence of around *29 degrees*

References

-O'Doherty, R.F. and Anstey, N.A., 1971, Reflections on amplitudes: Geophysical Prospecting, **19**, 430-458

-Burridge, R., and Chang, H.W., 1989, Multimode, one-dimensional wave propagation in a highly discontinuous medium: Wave Motion, **11**, 231-249

-Herrmann, F.J., 1991, The effect of detail on wave propagation: Towards an improved macro model parameterisation: M. Sc. thesis, Delft University of Technology

-Herrmann, F.J., and Wapenaar, C.P.A., 1992, Macro description of fine layering: proposal for an extended macro model: 62nd SEG meeting, New Orleans, 1263-1266

-Wapenaar, C.P.A., and Slot, R.E., 1994, Towards an extended macro model, that takes fine-layering into account: Jrnl. Seismic Explor., **3**, (accepted)