A GENERAL-APPLICATIONS DIRECT GLOBAL MATRIX ALGORITHM FOR RAPID SEISMO-ACOUSTIC WAVEFIELD COMPUTATIONS

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The purpose of this paper is to explain and illustrate a new matrix method for rapid wave propagation modeling in generalized stratified media, which has recently been applied to numerical simulations in diverse areas of underwater acoustics, solid earth seismology, and nondestructive ultrasonic scattering.

This report summarizes a portion of recent efforts jointly undertaken at NATO SACLANT and NORDA Numerical Modeling groups in developing, implementing, and testing a new fast general-applications wave propagation algorithm, SAFARI, formulated at SACLANT by Schmidt (1982). Historically, most algorithms for computing acoustic transmission loss, synthetic seismic time series, and ultrasonic beam scattering have been separate applications-specific programs, using a (local) Thomson-Haskell propagator matrix to recursively propagate the complete wavefield solution across all layers. In contrast, the present general-applications SAFARI program uses a Direct Global Matrix Approach to multilayer Green's function calculation. A rapid and unconditionally stable solution is readily obtained via simple Gaussian elimination on the resulting sparsely banded block system, precisely analogous to that arising in the Finite Element Method. The resulting gains in accuracy and computational speed allow consideration of much larger multilayered air/ocean/earth/engineering material media models, for many more source-receiver configurations than previously possible. The general multisource capability allows choice of number and location of point or line sources, for monofrequency transfer function, field contour or beam analysis, and broadband pulse modeling, in plane or cylindrical geometries, for a general n-layered system. The only effective limit is computer virtual memory, which on a VAX 11/780 + FPS 164, allows as many as 250 layers/100 receivers/50 sources/2000 Hz bandwidth.

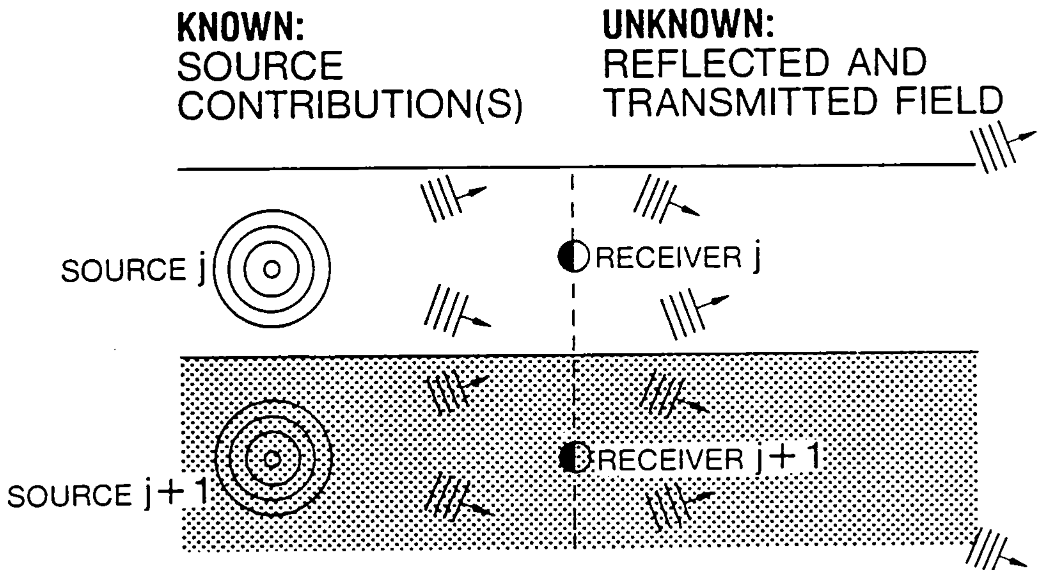
We demonstrate the validity and versatility of the SAFARI-DGM method by reviewing three practical examples of engineering interest, drawn from ocean acoustics, engineering seismology and ultrasonic scattering. Extension of these results to further infrasonic and atmospheric noise modeling (as well as nondestructive evaluation) is immediate.

References

Pekeris, C. L., 1948. "Theory of Propagation of Explosive Sound in Shallow Water." *Geol. Soc. Am. Memoirs*, no. 27.

Schmidt, H., 1982. "Excitation and Propagation of Marine Seismic Interface Waves (using a new Fast Field Program)," in: N. G. Pace (ed.), *Acoustics and the Seabed*, Institute of Acoustics Proceedings. Bath UK: University Press.

SAFARI NUMERICAL MODEL



SOLUTION TECHNIQUE

1) SOURCE CONTRIBUTION DECOMPOSED INTO UP AND DOWNGOING PLANE WAVES IN EACH LOCAL LAYER

2) CORRESPONDING PLANE-WAVE COMPONENTS OF UNKNOWN FIELD FOUND BY MATCHING BOUNDARY CONDITIONS IN ALL LAYERS ACROSS ALL INTERFACES

3) TOTAL GLOBAL FIELD AT ALL DEPTHS IS CALCULATED VIA SUPERPOSITION OF ALL LOCAL LAYER WAVEFIELDS
(*DEFINING DEPTH-DEPENDENT GREEN'S FUNCTION*)

4) TOTAL FIELD AT ALL RANGES IS CALCULATED BY NUMERICAL INTEGRATION OF DEPTH DEPENDENT GREEN'S FUNCTION OVER HORIZONTAL WAVENUMBER K_r
(*DEFIING FREQUENCY-DOMAIN TRANSFER FUNCTION*)

5) SYNTHETIC TIME SERIES FOUND BY NUMERICAL INTEGRATION OVER EACH FREQUENCY ω VIA INVERSE FOURIER TRANSFORM
(*DEFINING SYNTHETIC SEISMIC TIME SERIES*)

Figure 1.

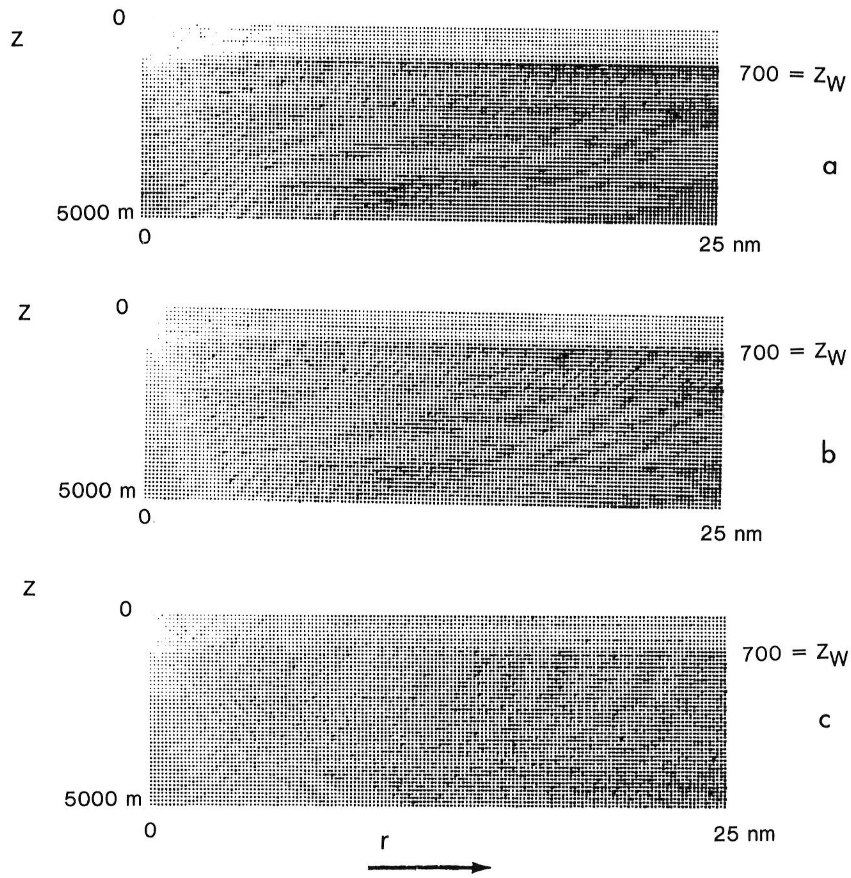


Figure 2. Depth-range contoured transmission loss fields (f = 10 Hz), for horizontal particle velocity (a), vertical particle velocity (b), and normal stress (pressure) (c). Range = 0—25 km; depth = 0—5000 m.

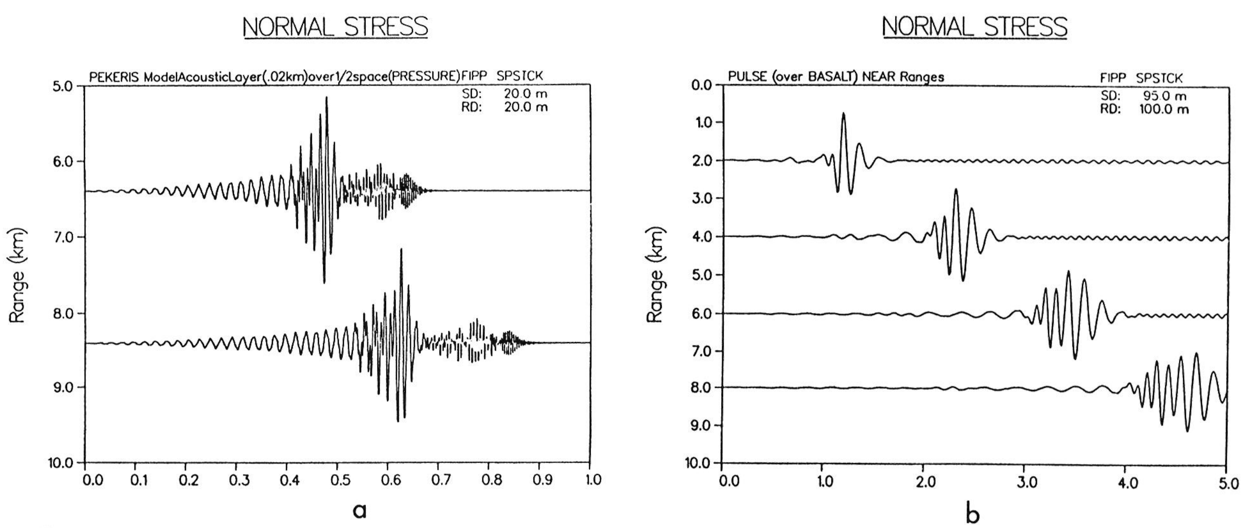


Figure 3. Multifrequency seismic pulse calculations: (a) High-frequency normal acoustic mode (f = 0, 450 Hz; after Pekeris, 1948) at 2 offset ranges, showing direct water and subsequent mode arrivals. (b) Very-low-frequency seismic interface (Scholte) wave (f = 0, 12 Hz) for shallow water waveguide over basalt, showing strong frequency dispersion over 4 offset ranges between 2 and 8 km ranges (after Schmidt, 1982).

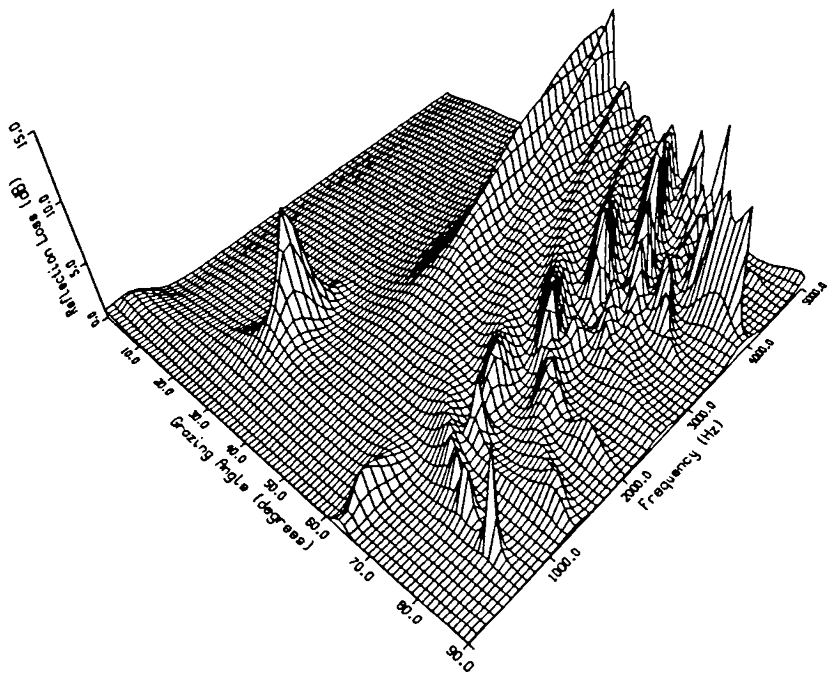


Figure 4a. High-frequency reflection loss as a function of frequency and grazing angle for Arctic under-ice propagation. 2 m thick ice sheet (25 solid layers) overlying 4000 m deep sound channel.

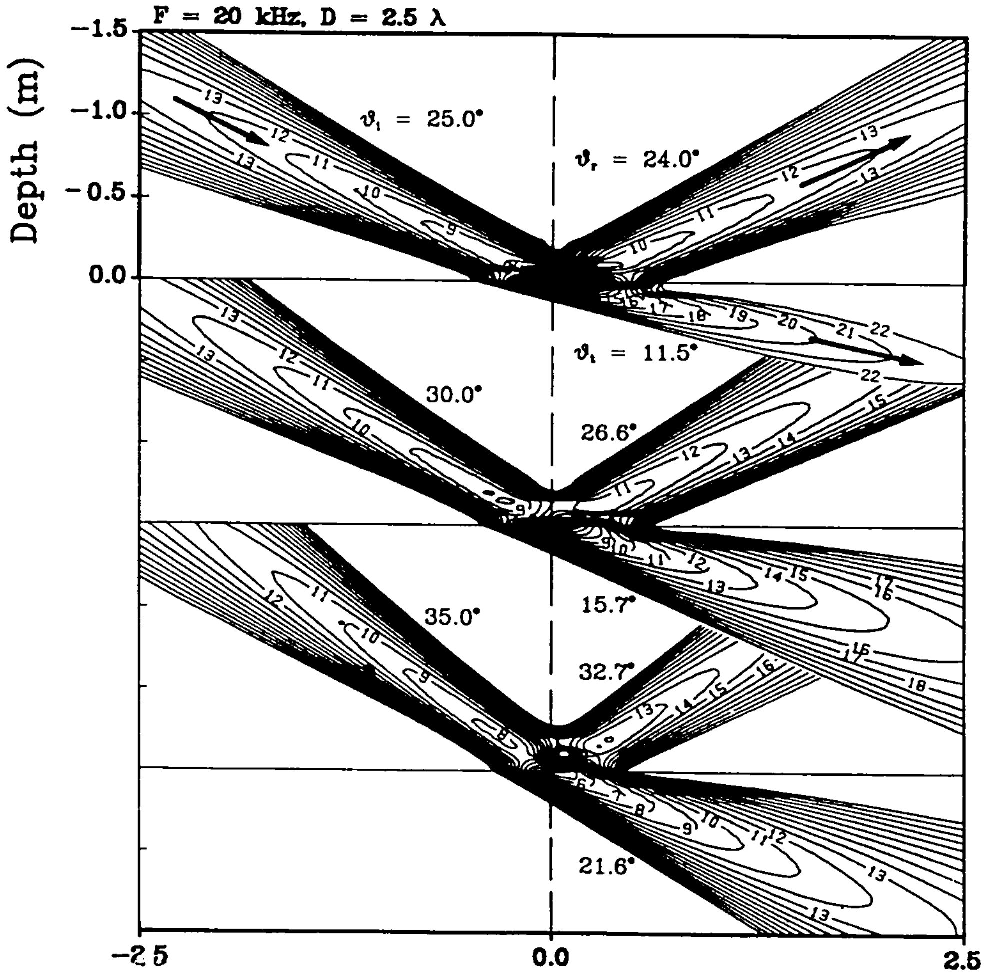


Figure 4b. Very-high-frequency beam reflection and transmission at a water/sand-silt bottom interface (from Schmidt and Jensen, 1984).