Ray-Reflectivity Method

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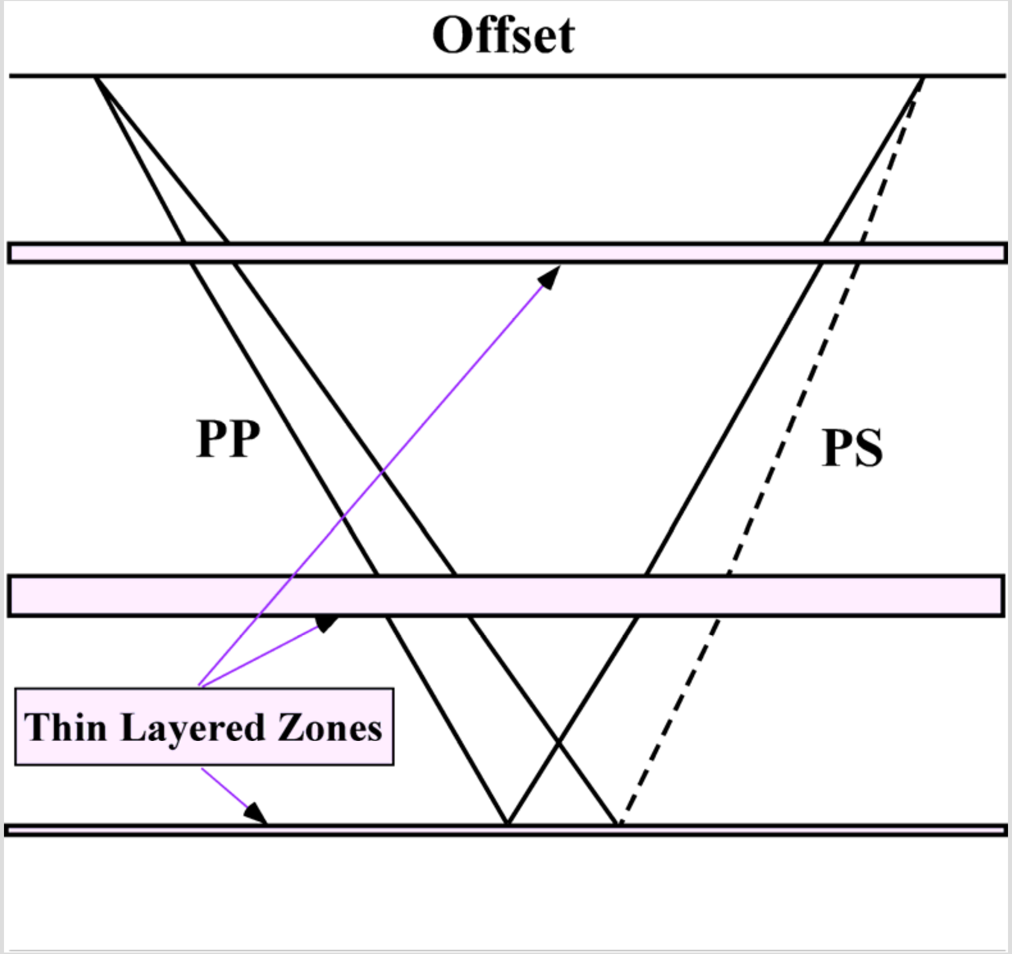
Overview of Method

- **Synthetic seismograms using a combination of Asymptotic Ray Theory and Matrix Methods.**
- **Plane parallel medium.**
- ***Thick* layers separated by *Thin* layered zones.**
- **Geometrical spreading in thick layers only.**
- **R & T coefficients at interfaces replaced by *reflectivities* and *transmittivities* obtained using propagator matrix methods.**
- **Frequency dependent – *FFT* to time domain.**

Schematic of a Realistic Model



Vector Amplitude of Contributing Rays

$$\mathbf{u}(r,0,t) = \mathrm{FFT}^{-1}\left(F(\omega) \sum_{Rays} \left\{ \frac{\prod_{R\&T} R(p,\omega)}{L} \exp\left[i\omega\tau_{Ray} \right] \right\} \begin{bmatrix} Q_v \\ Q_h \end{bmatrix} \right)$$

Source & Receivers on Surface

L **– frequency independent geometrical spreading of a ray.**

***F*(ω) – Fourier transform of band-limited source wavelet.**

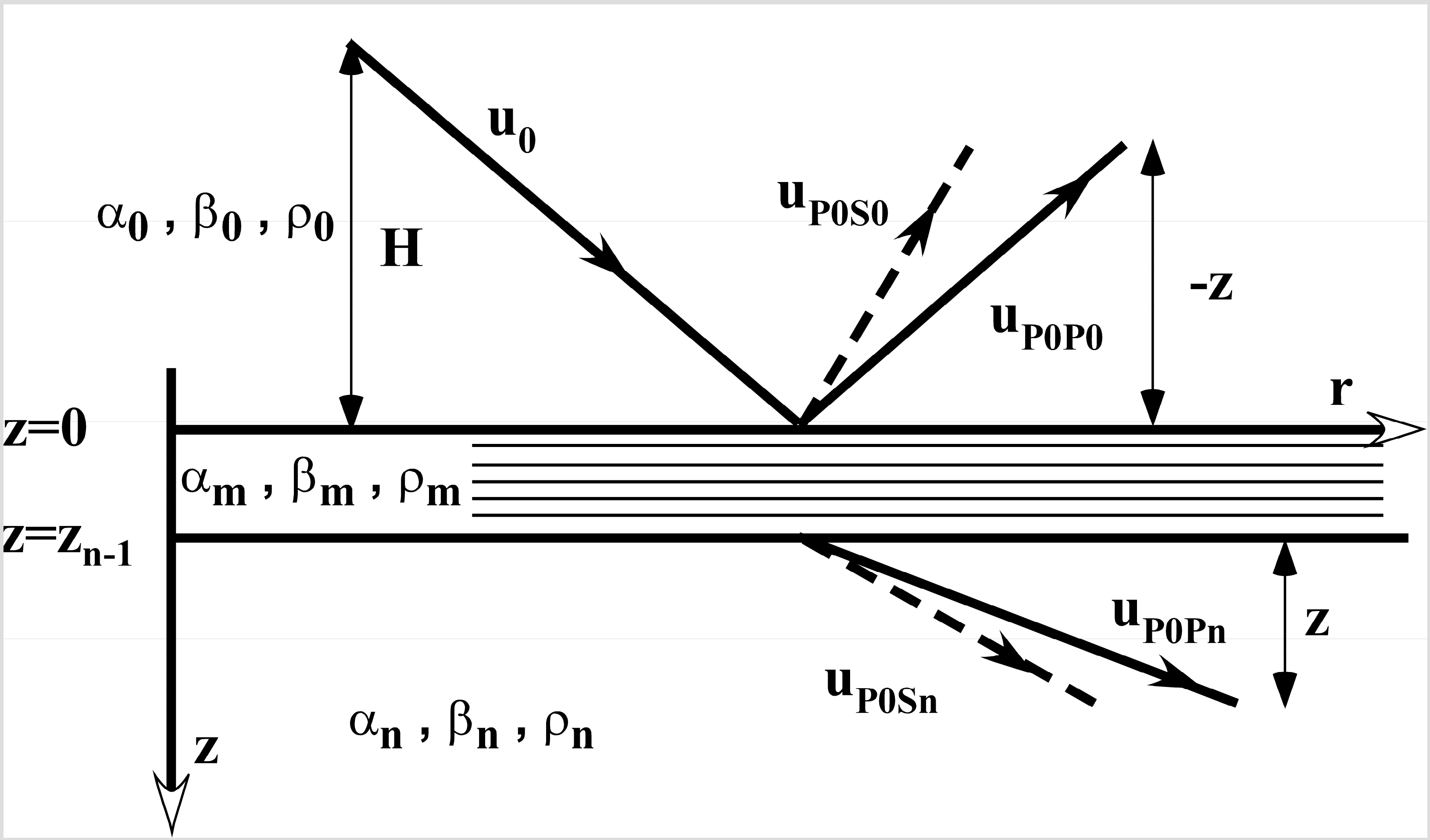
Π R(p, ω) – product of frequency dependent reflectivities and transmittivities along a ray.

$(Q_V, Q_H)^T$ – frequency independent surface conversion coefficient vector.

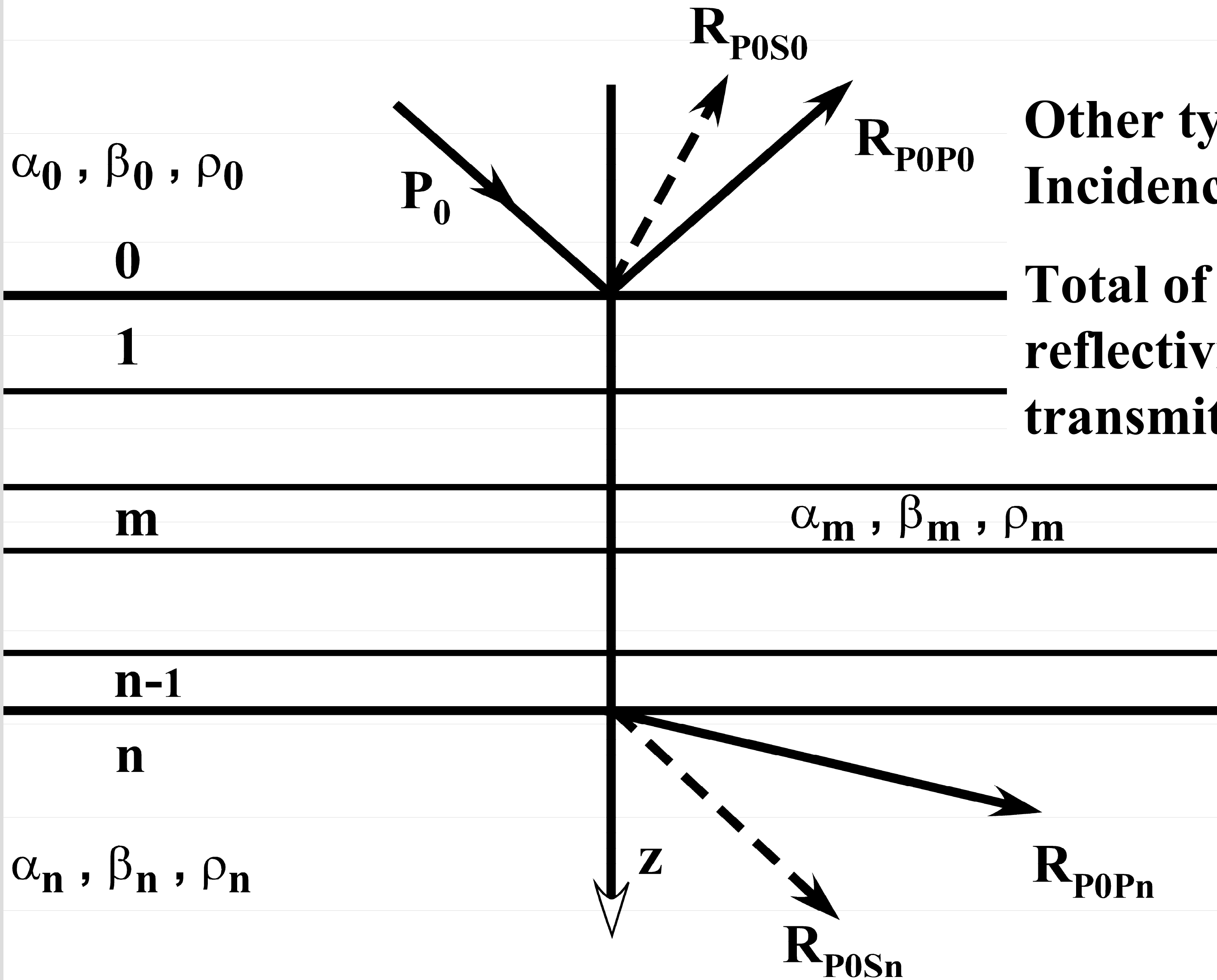
τ_{Ray} - travel time of a ray.

***p* – ray parameter.**

Displacements Due to P Wave Incidence



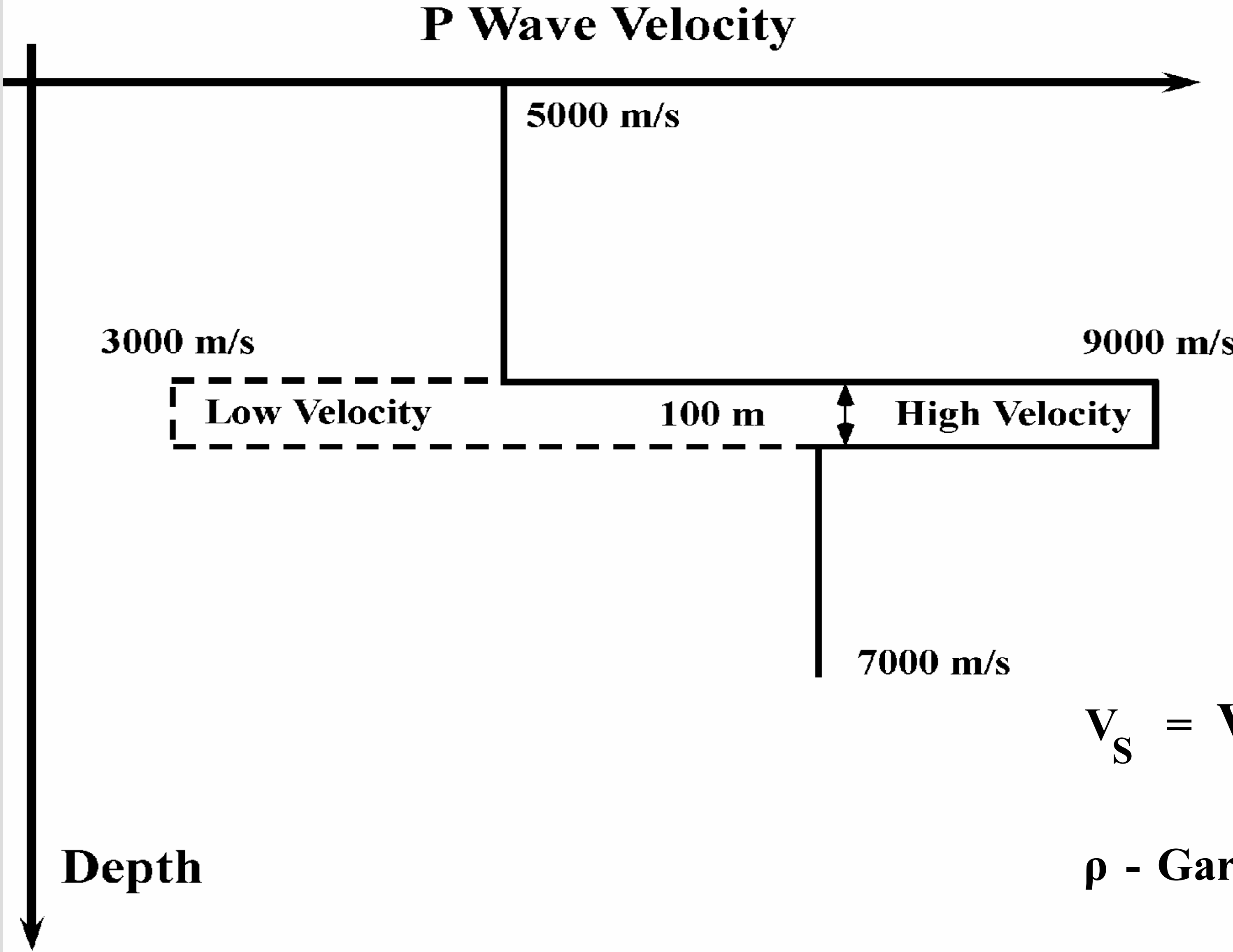
Analogue of P_0 - Plane Wave Incidence



Other types of Incidence: S_0, P_n, S_n .

Total of 16 possible reflectivities & transmittivities.

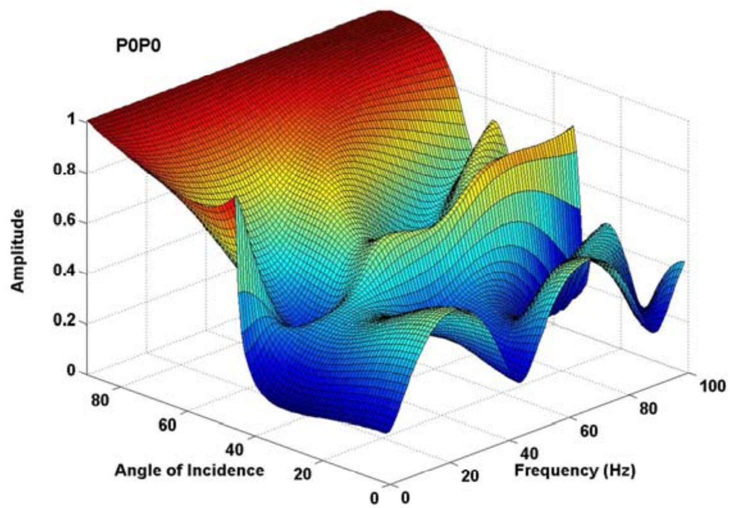
Simple Geological Example

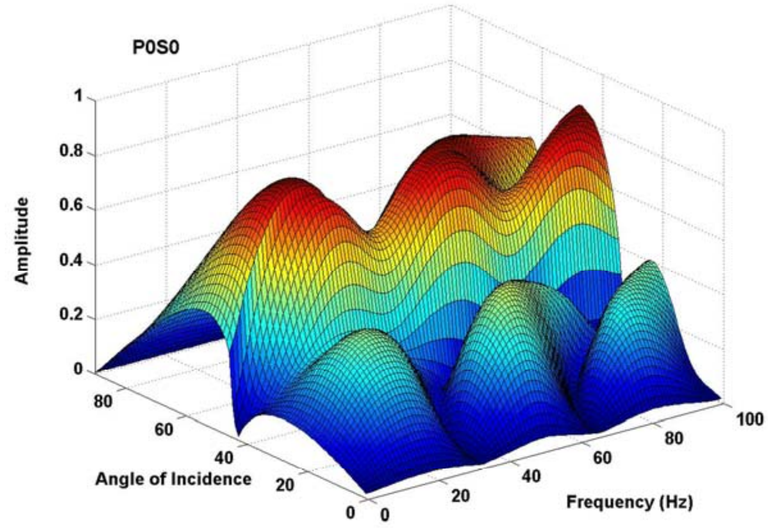


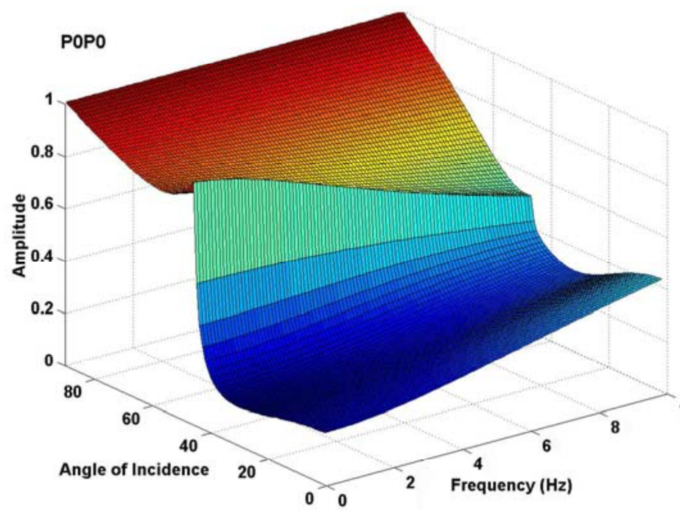
$$V_S = V_P / 3^{1/2}$$

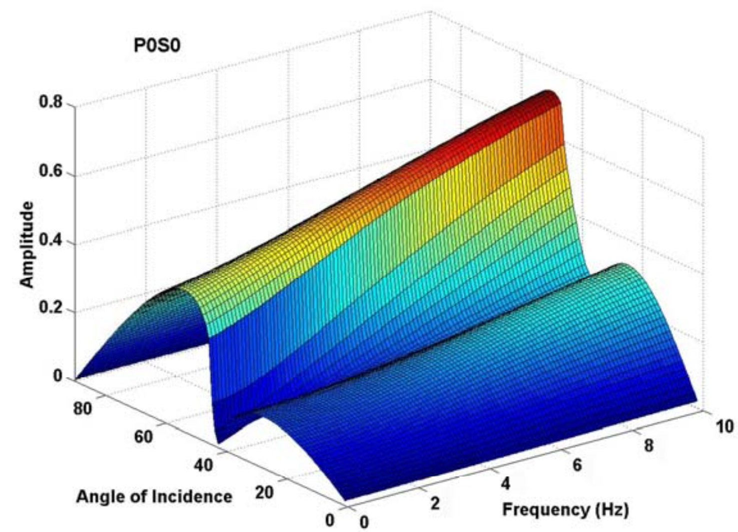
ρ - Gardner's Law

P0P0 and P0S0 Reflectivity – High Velocity Layer

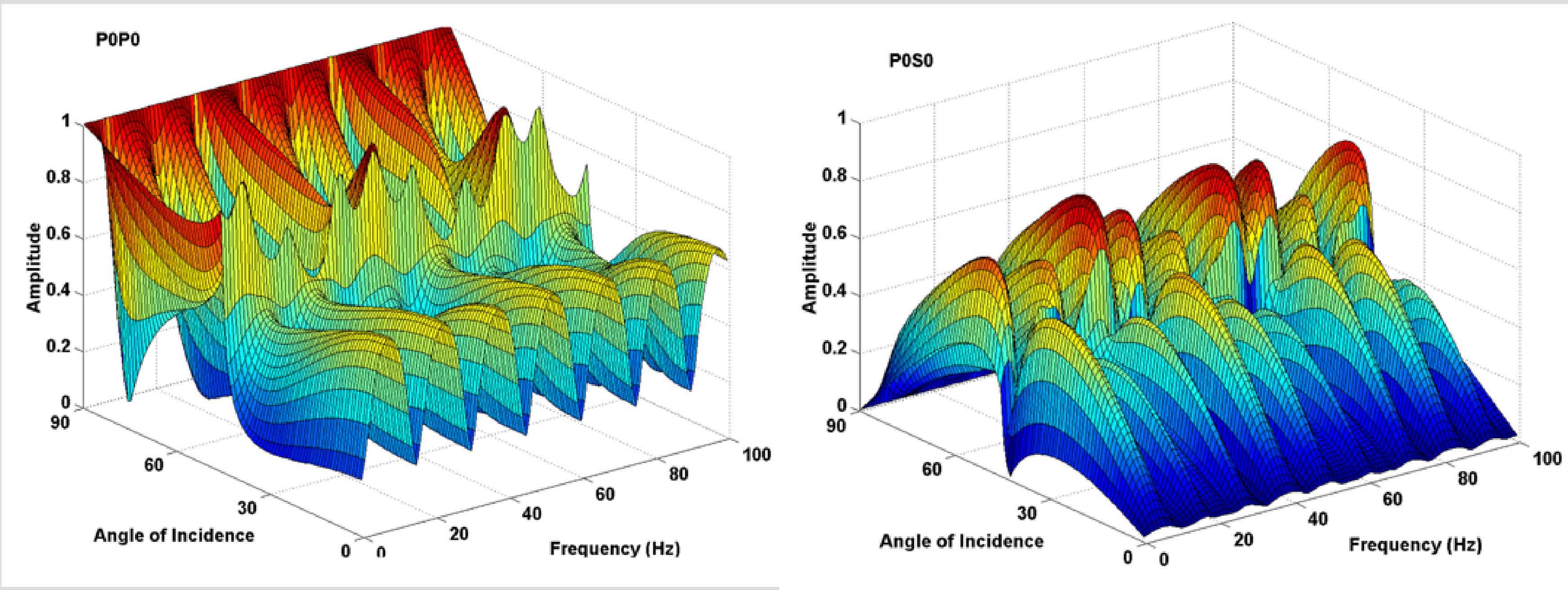




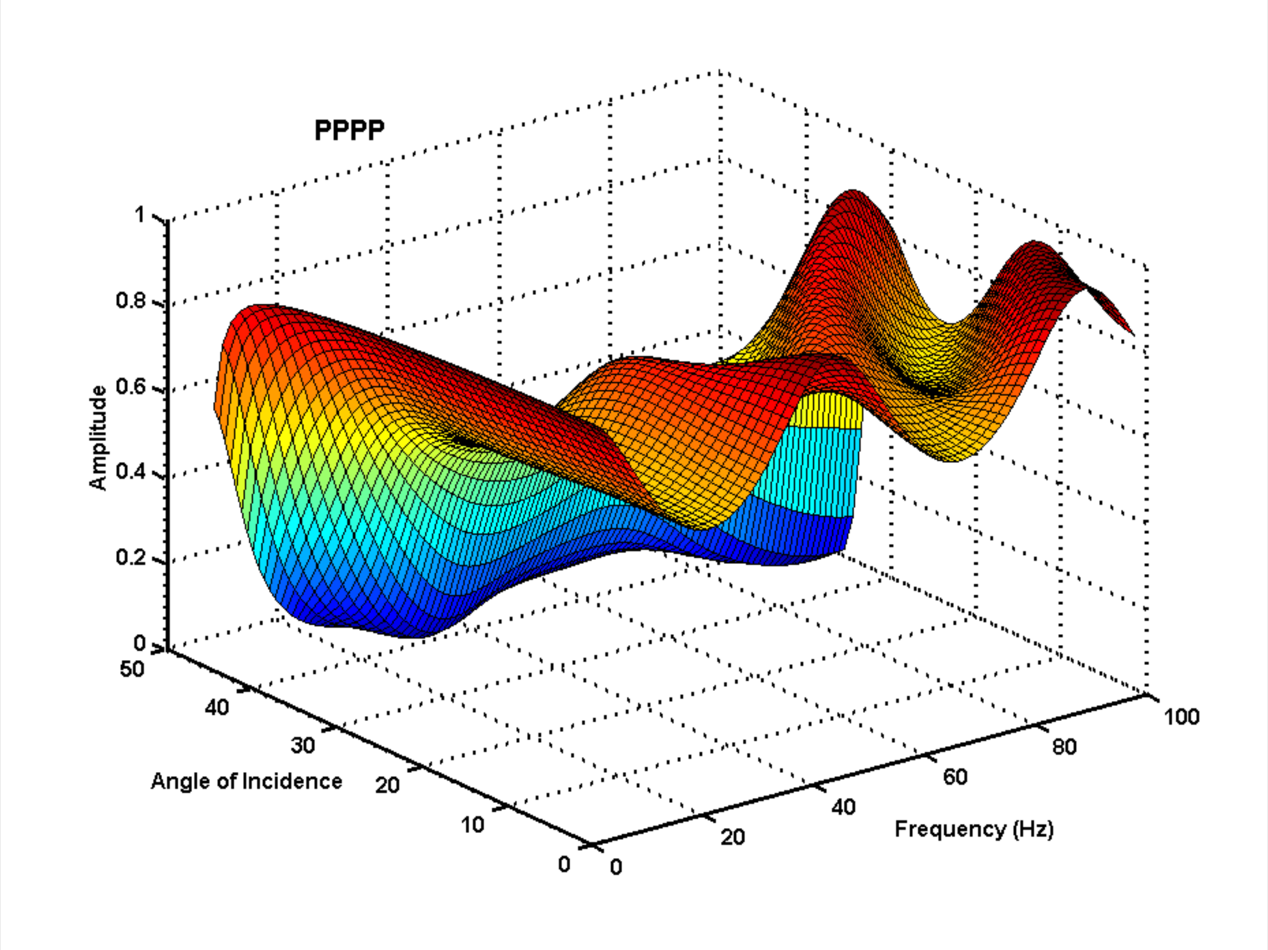




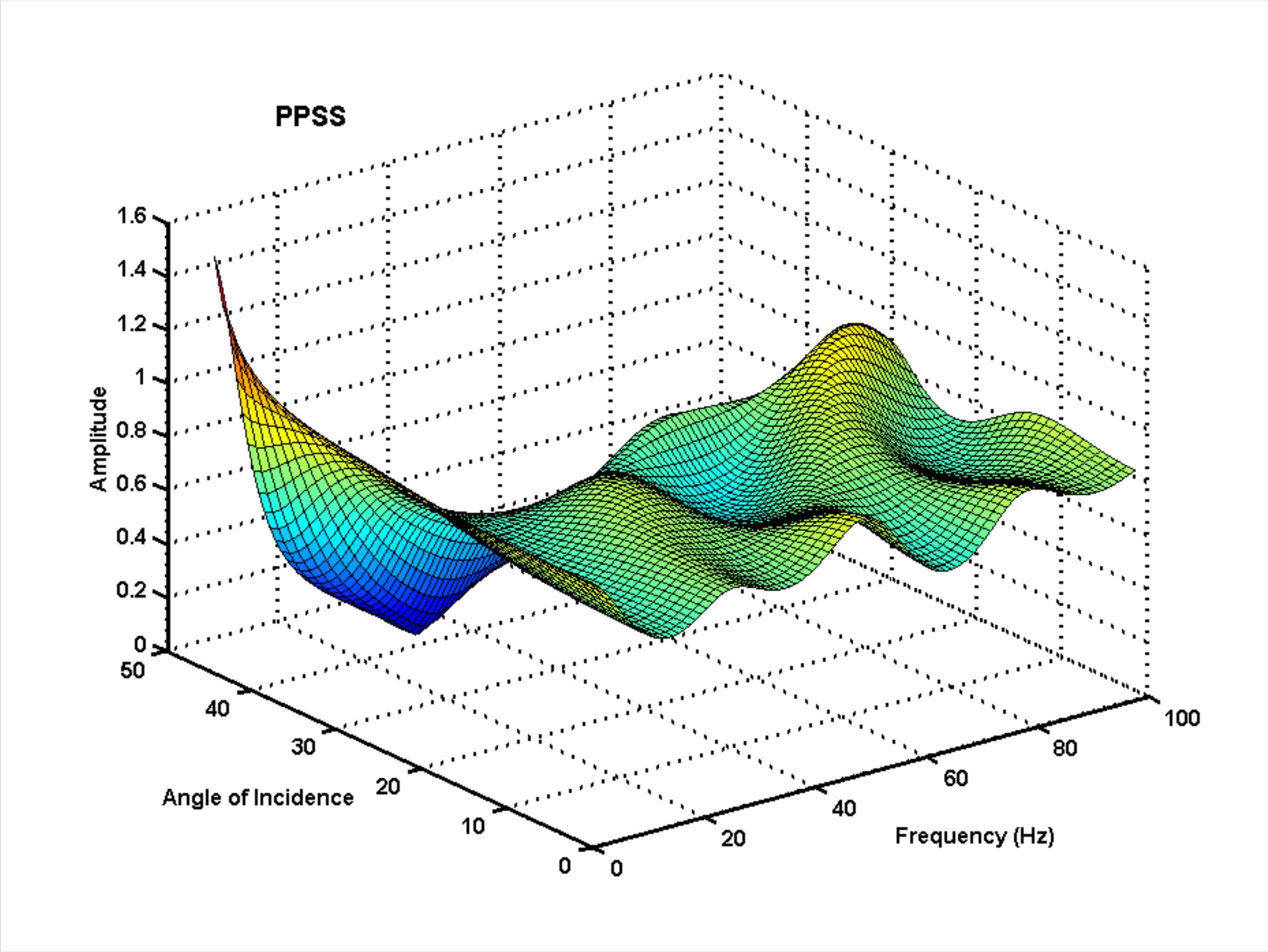
P0P0 and P0S0 Reflectivity Example – Low Velocity Layer



PPPP – Product of P0Pn and PnP0 Transmittivities
High Velocity Layer

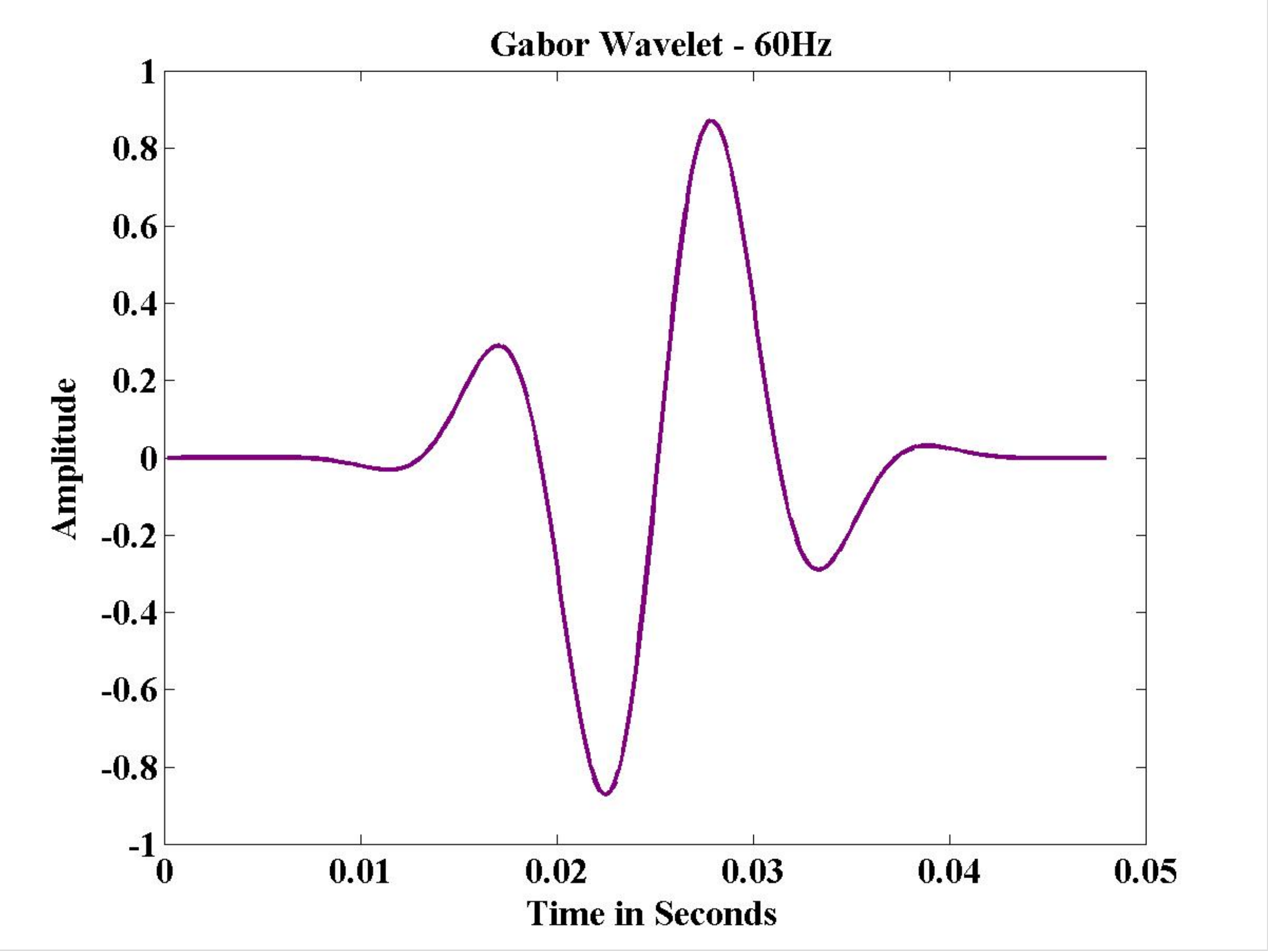


PPSS – Product of P0Pn and SnS0 Transmittivities
High Velocity Layer

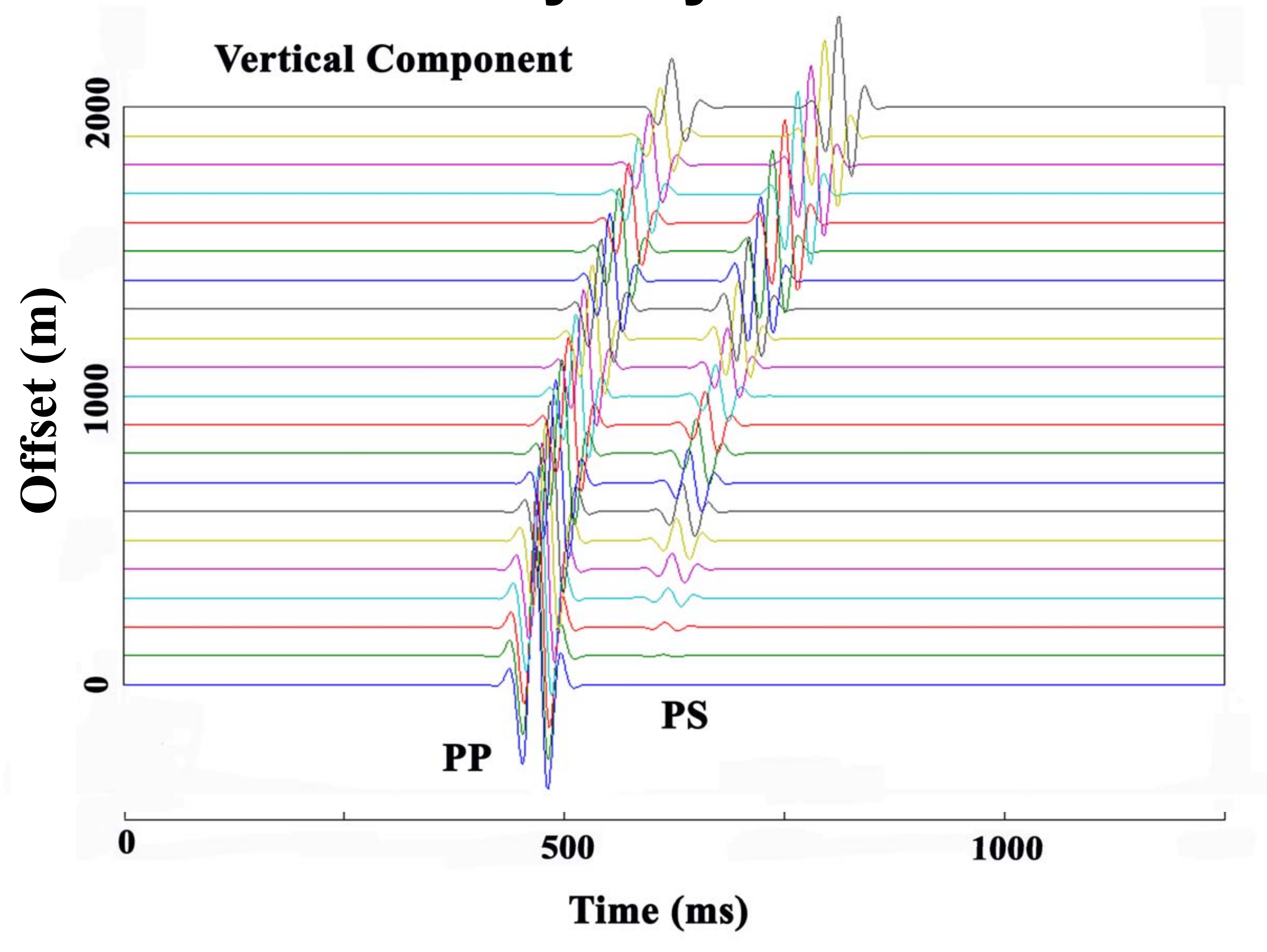


Gabor Wavelet: $f(t) = \sin(2\pi f_0 t) \exp[-(2\pi f_0 t/\gamma)^2]$

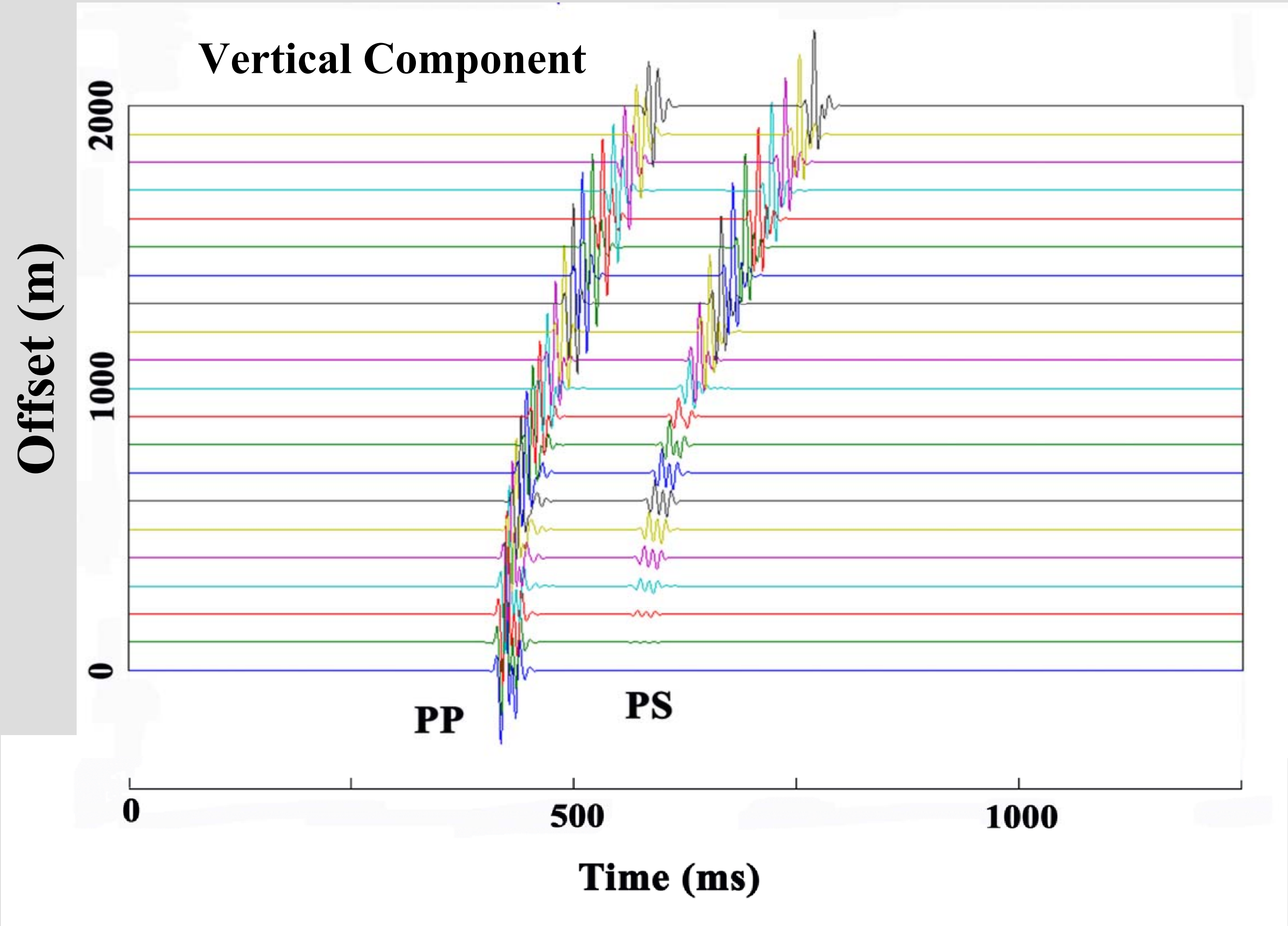
$F(\omega) = FFT[f(t)]$: $F(\omega) \neq 0 \approx (0 < f_0 < 2f_0)$



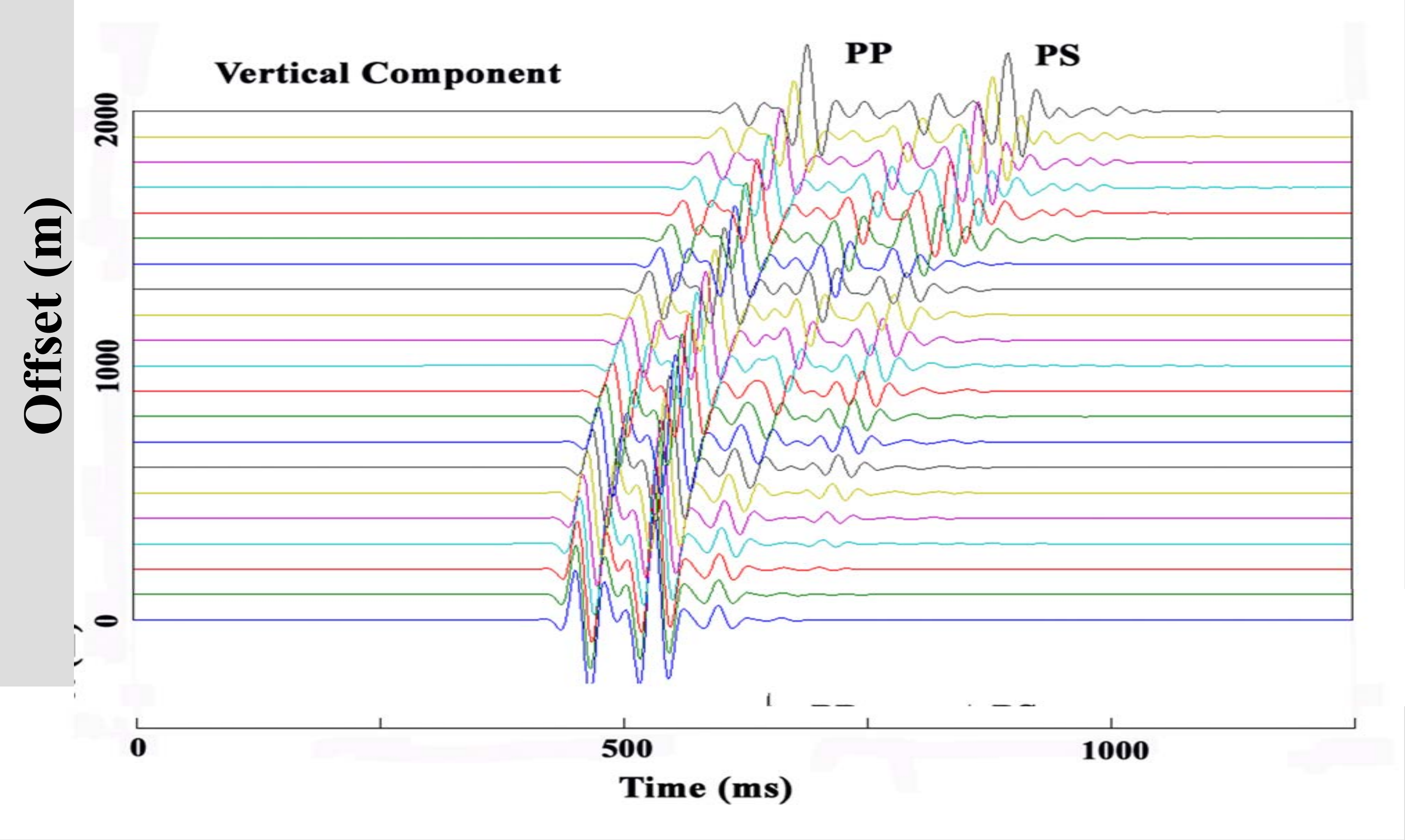
PP and PS Reflections From High Velocity Layer: 30Hz



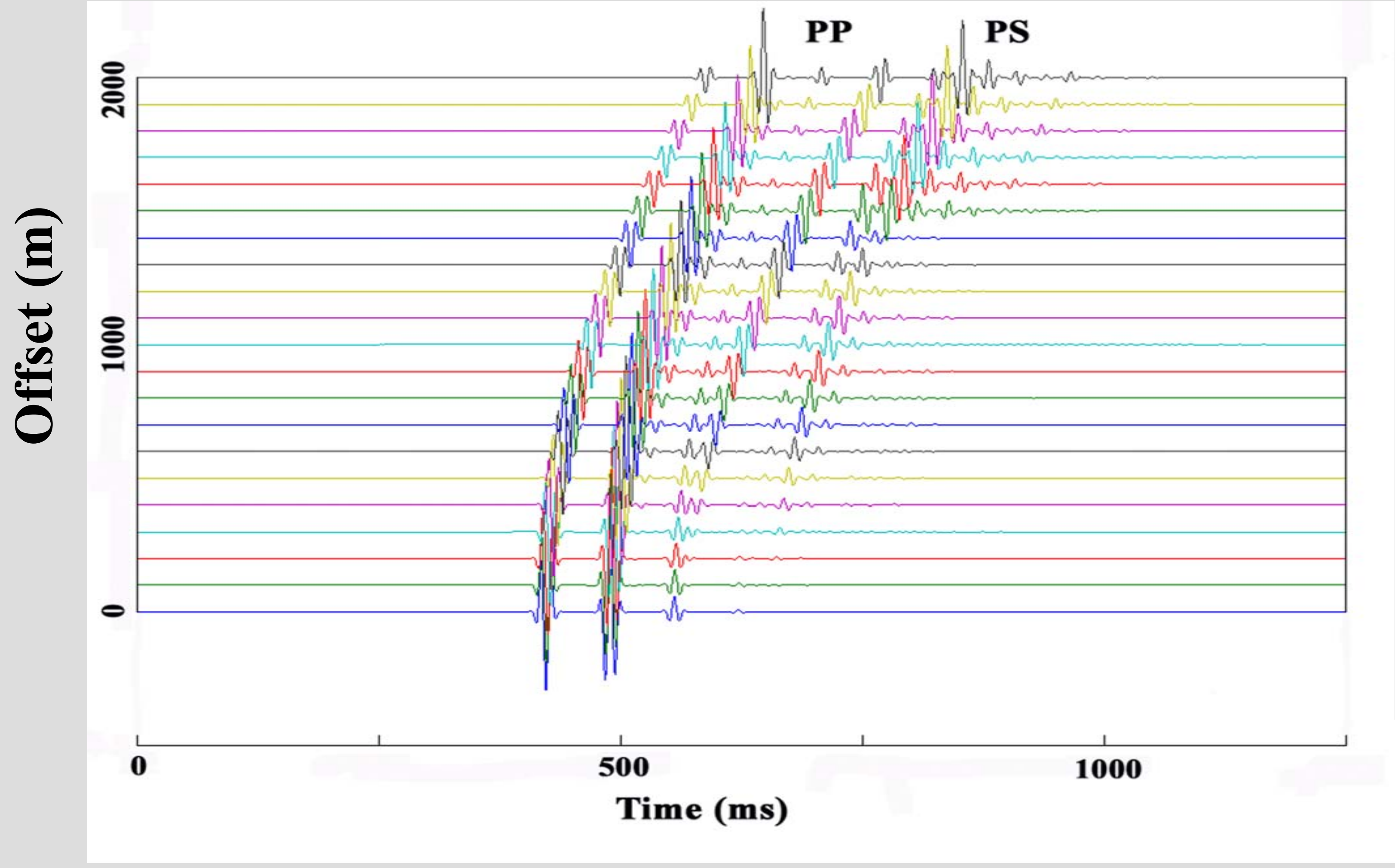
PP and PS Reflections From High Velocity Layer: 90Hz



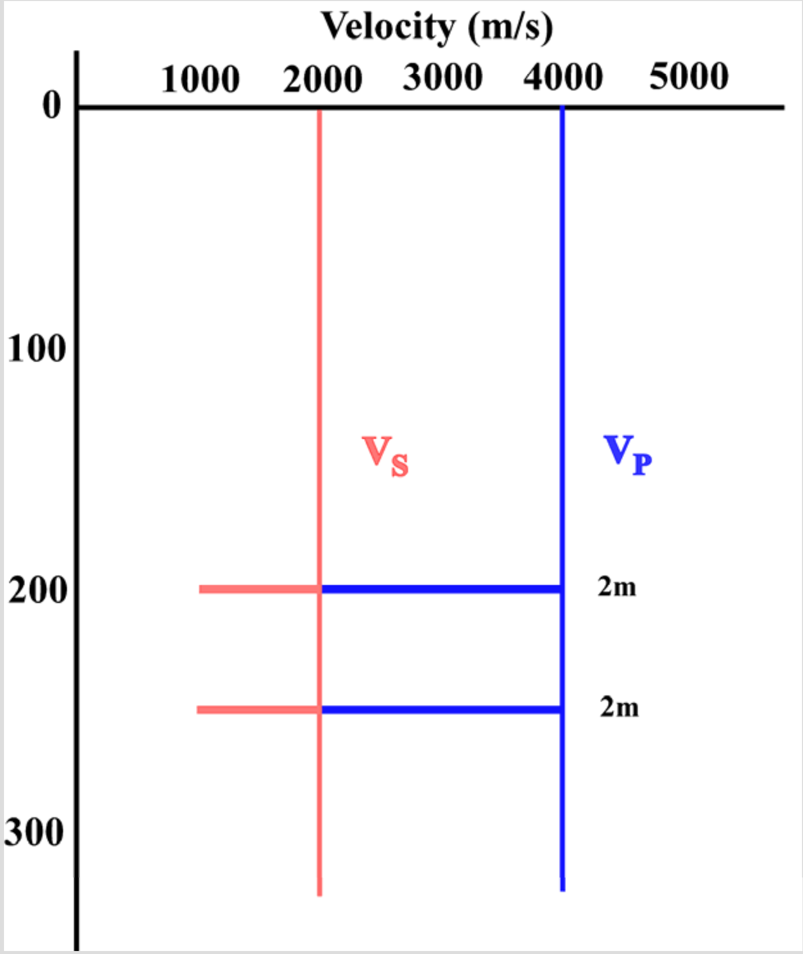
PP and PS Reflections From Low Velocity Layer: 30 Hz



PP and PS Reflections From Low Velocity Layer: 90 Hz

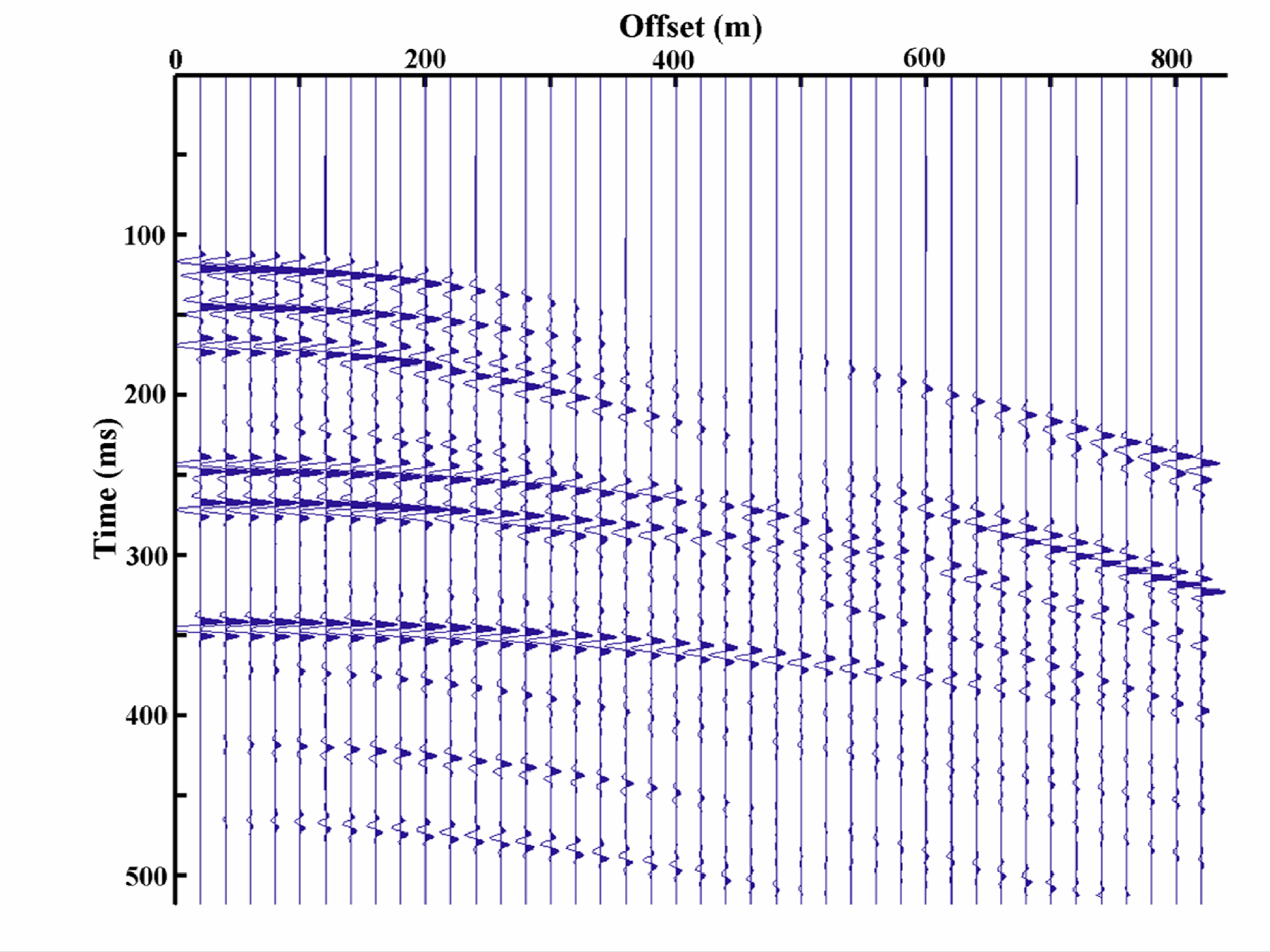


Coal Seam Model (Muller)

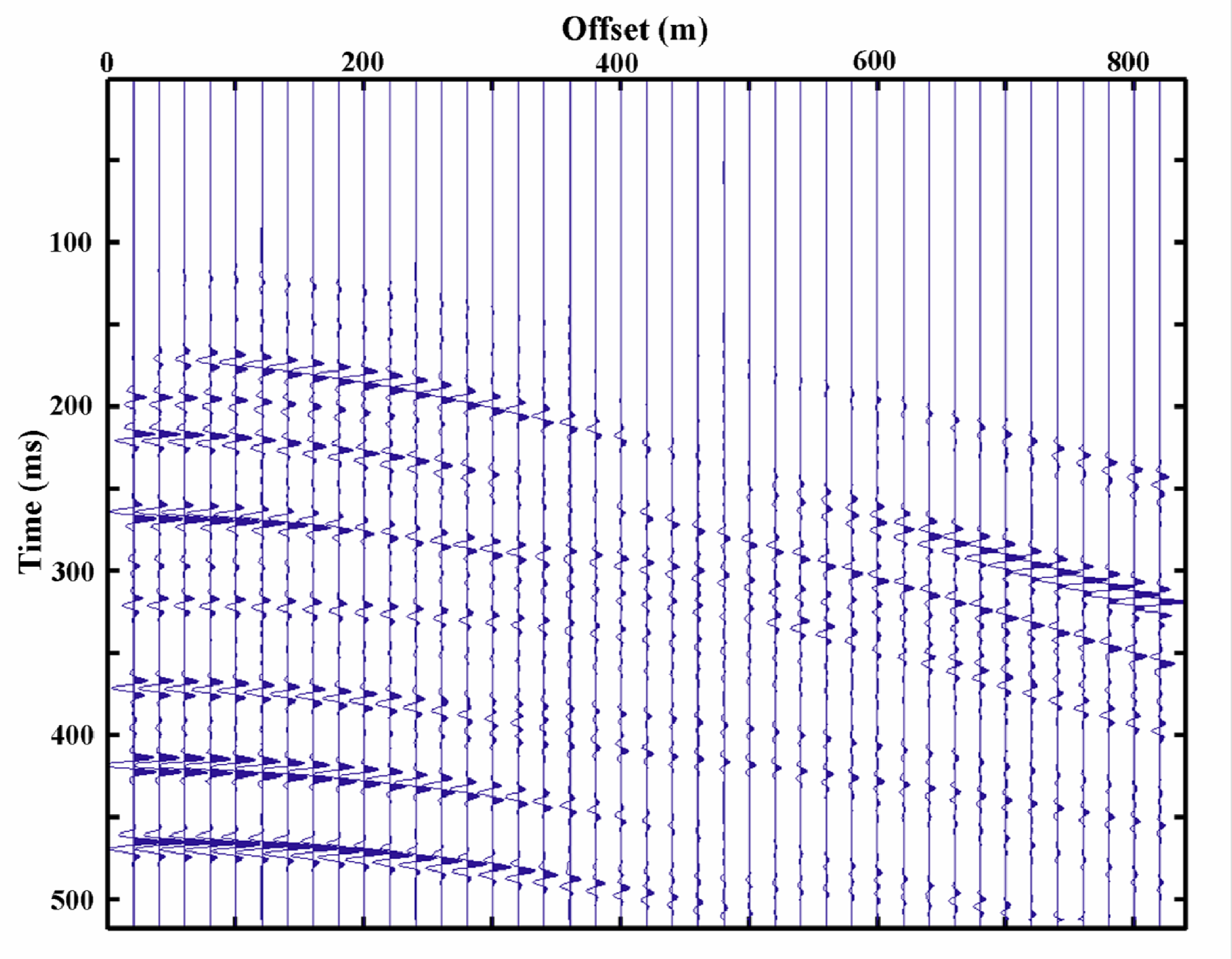


Synthetic traces that follow for this model contain primaries, multiples and rays with a maximum of up to 3 mode conversions

Vertical Component of Displacement



Horizontal Component of Displacement



Summary

- **Modification of the reflectivity method by introducing thin layered zones between thick layers allows for the inclusion of numerous layers where ray theory may be invalid.**
- **R & T coefficients replaced by matrix based frequency dependent analogies.**

- **The thick layers introduce geometrical spreading and approximate arrival times allow for arrival identification of wave trains related to a thin bed.**
- **Applications in coal bed sequences (CBM) has being investigated. (San Juan Basin)**
- **Ancillary software for the modeling of tuning effects.**
- **Applications to other structures where the pay zone(s) are *thin*. (Cold Production)**
- **Possible use in Time Lapse problems.**

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