Ground-roll filtering using local instantaneous polarization

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ABSTRACT

A ground-roll filtering procedure is outlined, which uses two-component seismic data. This process uses the localized slant stack of the two components and their instantaneous phase to identify and suppress ground roll. The procedure should be appropriate for dispersive and non-dispersion events.

INTRODUCTION

Ground roll or Rayleigh waves are generally regarded, at best, as a nuisance. Because they basically travel horizontally though, they can usually be suppressed in the field by geophone arrays. Furthermore, the remaining ground roll recorded is usually low frequency and low velocity, so it is conventionally attenuated by various kinds of low-cut filters or velocity filters. Each of these event suppression methods has its limitations, however, and may also damage the desired signal. Field arrays will attenuate any non-vertically traveling events including high-angle reflections and diffractions. A low-cut filter will clearly reduce low-frequency signals as well as noise. Velocity filters may introduce undesirable artifacts. Promising methods for ground-roll rejection lie in the use of three-component (3-C) geophones. A number of authors (e.g. Kanasewich, 1981; Shieh and Herrmann, 1990) have attempted to use the polarization character of ground-roll motion to identify and suppress it.

Recall that at the surface of a half-space, ground roll has retrograde elliptical motion (Bullen, 1963; Pilant, 1979). The horizontal displacement U_x and vertical displacement U_z of the Rayleigh wave propagating at the surface along x at time t are given by:

$$U_x = \frac{ik\eta^2 e^{i(kx-wt)}}{2} \tag{1}$$

$$U_z = k\left[-\left(1-\delta^2\right)^{1/2} + \frac{\left(1-\frac{\eta^2}{2}\right)}{\left(1-\eta^2\right)^{1/2}}\right] e^{i(kx-wt)} \tag{2}$$

where c, k, w are the ground-roll velocity, wavenumber, and frequency, respectively and α, β are the P-wave and S-wave velocities, $\delta = c/\alpha$, $\eta = c/\beta$.

Note the c has a value between 0 and β and can be found from the following equation (d'Arnaud Gerkens, 1989):

$$\eta^3 - 8\eta^2 + 8\eta(3-2\gamma) = 16(1-\gamma)\,, \tag{3}$$

where $\gamma = \beta/\alpha$

For $\gamma^2 = 3$ then $c = 0.9194\ \beta$, and $U_z/U_x = 1.47$.

A critical characteristic of ground roll which allows its identification is the phase advance of U_x with respect to U_z. It is this aspect of ground roll which will be used in this proposal for its suppression.

For a more complex medium, say several layers over a half space, interface waves waves generally become dispersive. That is, velocity is a function of frequency. Grant and West (1965) state that in vertically inhomogeneous media there appears to be a recognizable Rayleigh-type motion which exhibits a sort of retrograde-elliptical motion at the surface. Thus this proposed method may be applicable to more general Rayleigh-type waves.

METHOD

For simplicity, consider a two-component geophone with the ground-roll propagating in the direction of the radial (in-line) channel. Take the local slant stack (over about 11 traces) of each channel to produce two p-t local decompositions. Next find the instantaneous phase of the vertical traces in p-t space. Where there is ground roll, the instantaneous phase of the horizontal traces should lead that of the vertical traces by $\pi/2$. We can then de-emphasize those points on the original p-t traces which have intantaneous phase differences of $\pi/2$. We would then inverse transform the p-t decomposition back to x-t and repeat the procedure for all local "trace windows" of all gathers (see Figure 1).

CONCLUSION

A proposal procedure has been outlined which uses multicomponent seismic data to attenuate ground roll. The process uses the local slant stack to create traces with given slownesses (p-t traces). Next, we find the instantaneous phase of the horizontal and vertical p-t traces and search for $\pi/2$ phase differences in them. Values on p-t traces that exhibit this phase difference will be suppressed. Ground roll is attenuated in this manner.

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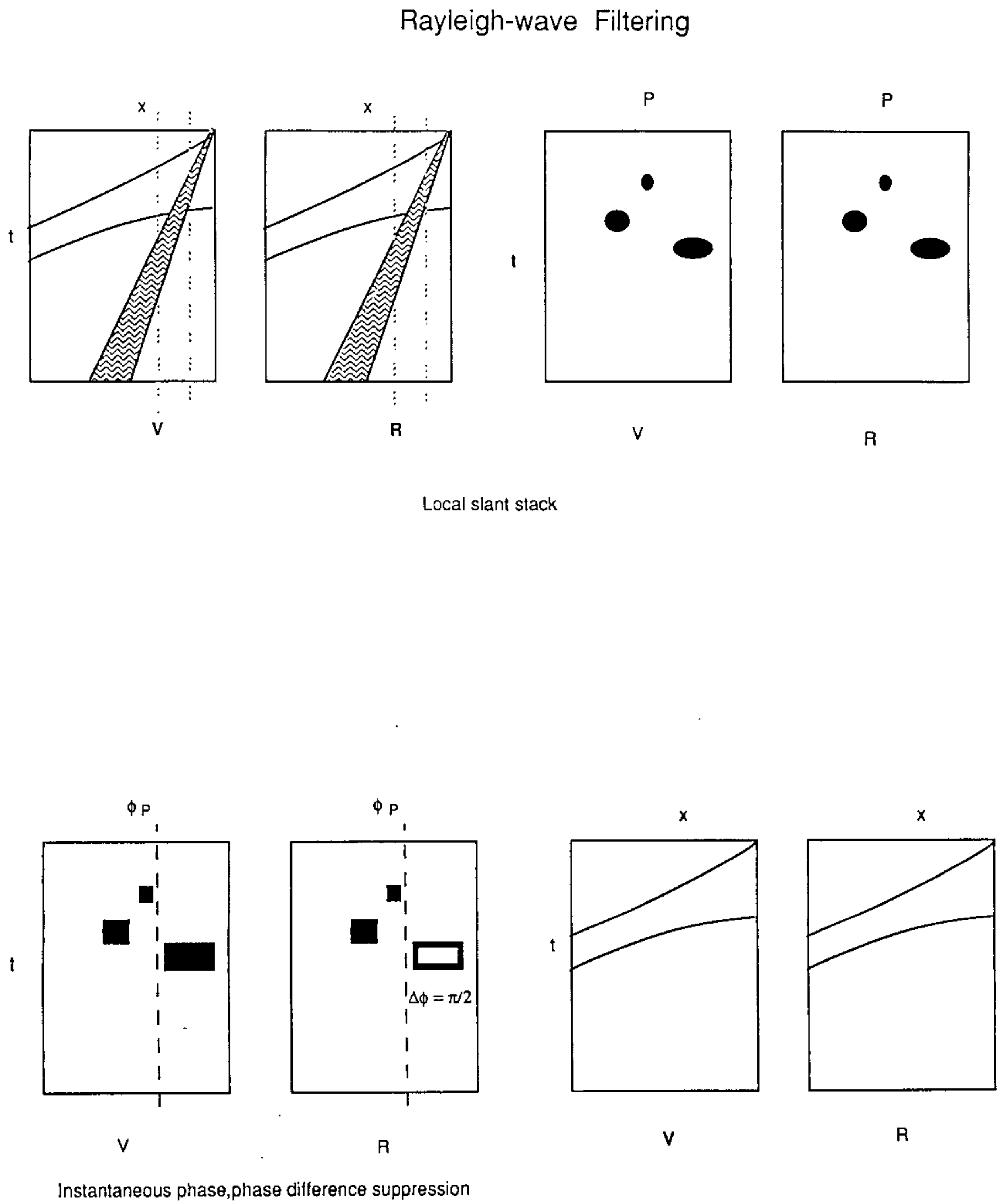

Rayleigh-wave Filtering
x
x
P
P
t
t
V
R
V
R
Local slant stack
ϕ P
ϕ P
x
x
t
t
Δϕ = π/2
V
R
V
R
Instantaneous phase,phase difference suppression

Figure 1.