Exploration Geophysics (1997) ***28****, 147-149*

DMO in the Radon Domain

Cheng-Shu Wang
Vector Seismic Data Processing Inc.,
Denver, CO, USA.

Mike Hall
Seismic Image Software Ltd.,
Calgary, AB, Canada.
Phone +1 403 233 2140
Facsimile +1 403 266 2685

ABSTRACT

A new dip-moveout (DMO) processing technique is proposed. The method is based on an integral DMO method in the Radon domain called Radon DMO, which is especially applicable to irregularly sampled 3-D datasets. Radon DMO offers several advantages for processing surveys with irregularly sampled design or acquisition characteristics, common problems for land and Ocean Bottom Cable 3-D surveys in particular. First, the Radon DMO operator is nonaliased and dealiasing. Missing traces do not cause spatial aliasing, precursor noise, or unbearable distortions of phase and amplitude. Second, Radon DMO does not require that input traces belong to one offset bin. Input traces can be organised from multiple offset bins in the same azimuth grouping to perform Radon DMO. Third, the DMO-corrected output can be either stacked or unstacked, which enables the full range of post-DMO processing including post-DMO velocity analysis.

The Radon DMO operator directly maps data from the NMO-corrected time domain to the DMO wavefield in the Radon domain. The impulse responses of Radon DMO are hyperbolas. The method is built upon a process that transforms a single, NMO-corrected trace into multiple traces spread along hyperbolas in the Radon domain. Most integral methods include the application of a 45° phase shift, as well as offset, time, and frequency-dependent gain factors when spreading the traces along ellipses. Such compensations are generally unnecessary with Radon DMO, which greatly simplifies program development and reduces the number of critical elements to control. By eliminating costs associated with gain factor application, the added costs for inverse Radon transform are alleviated. Total costs compare well with conventional integral DMO methods.

Keywords: DMO, 3-D, artefacts, irregular sampling, survey design, Radon, aliasing

INTRODUCTION

It is common for land, transition zone and Ocean Bottom Cable 3-D field layouts to yield irregularly sampled data with respect to fold, azimuth and offset. With the trend towards ever wider marine deployments this is also becoming a feature of marine 3-D seismic surveys. This phenomenon is exacerbated by surface obstacles and cost constraints. Population deficiencies are exaggerated in the common offset domain, such that the most efficient F-K method for DMO correction cannot be used. Integral DMO methods are more commonly implemented for 3-D data largely for practical reasons, but these methods can also be adversely affected by irregularly sampled data (Ronen, 1994).

To solve these problems, integral methods should be nonaliased (Hale, 1991), which means they introduce no precursor noise with regularly sampled data. Perhaps more importantly, the DMO operator must be dealiasing, such that no precursor noise is generated with irregularly sampled data. The Radon DMO method presented here can largely resolve those difficulties.

Conventional integral DMO methods, which are similar to the FK method (Hale, 1984), yield impulse responses that have the elliptical shape as in equation (1).

$$\frac{t_0^2}{t_n^2}+\frac{x^2}{h^2}=1 \quad , \tag{1}$$

where t_n is normal-moveout-corrected (NMO) time before DMO,
t_0 is the time after DMO,
h is half source-receiver offset, and
x denotes lateral distance along the common-midpoint (CMP) axis.

In performing integral DMO, traces are mapped along ellipses. After DMO correction, constructive and destructive interference yield the zero-offset reflections. Implementation of integral DMO must be in the offset domain and data must be regularly sampled.

DMO METHOD IN THE RADON DOMAIN

Robinson (1982) defined the Radon transform as

$$U_R(\tau,p)=\int_{-\infty}^{\infty}u(x,px+\tau)dx \quad , \tag{2}$$

where $u(x,t)$ is a 2-D function in the space-time domain,
$U_R(\tau,p)$ is its Radon transform,
τ is the intercept, and
p is the slope.

The Radon transform has the property that a point in one domain (eg, space-time) will transform to a line in the other domain (eg, Tau-p) and vice-versa.

The Radon map (Gelfland, 1966) of the DMO ellipse denoted by equation (1) is the hyperbola

$$\tau^2=t_n^2+p^2h^2 \quad . \tag{3}$$

For the Radon DMO method, traces are directly mapped along hyperbolas in the Radon domain. All hyperbolas should intersect at one point (τ,p_0), producing a strong amplitude at this location. Figure 1b describes this phenomenon. After the inverse Radon transform, only the reflection remains. Specialised features are not necessary to design the amplitudes and phases for each point on the hyperbolas when the traces are spread in the Radon domain. This sharp focussing of energy under the Radon transform may be compared to the incomplete destructive interference

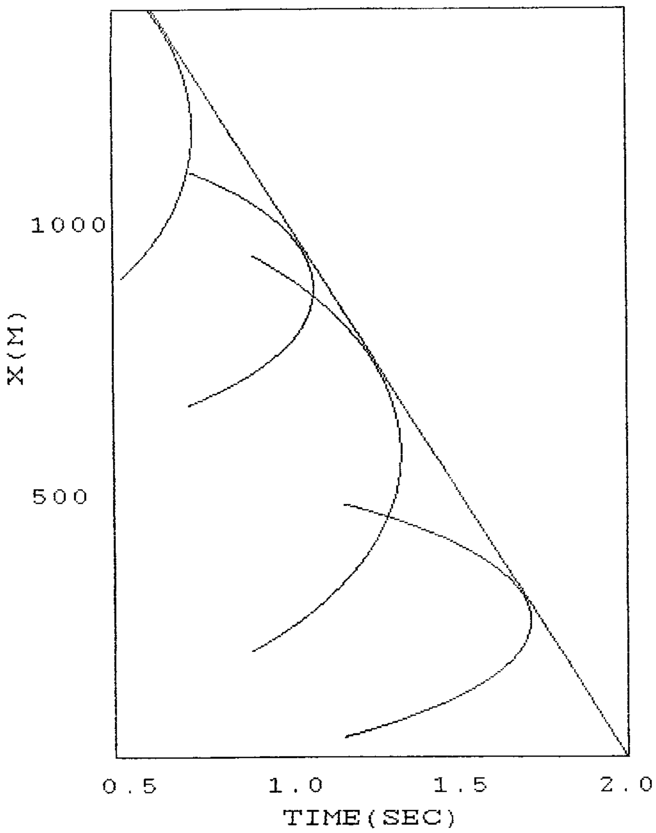

Figure 1a

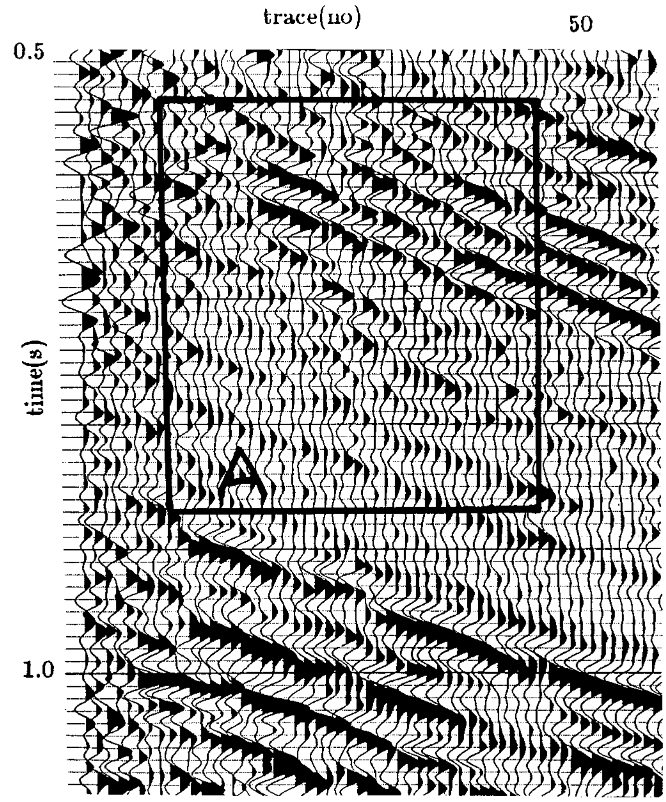

Figure 2a

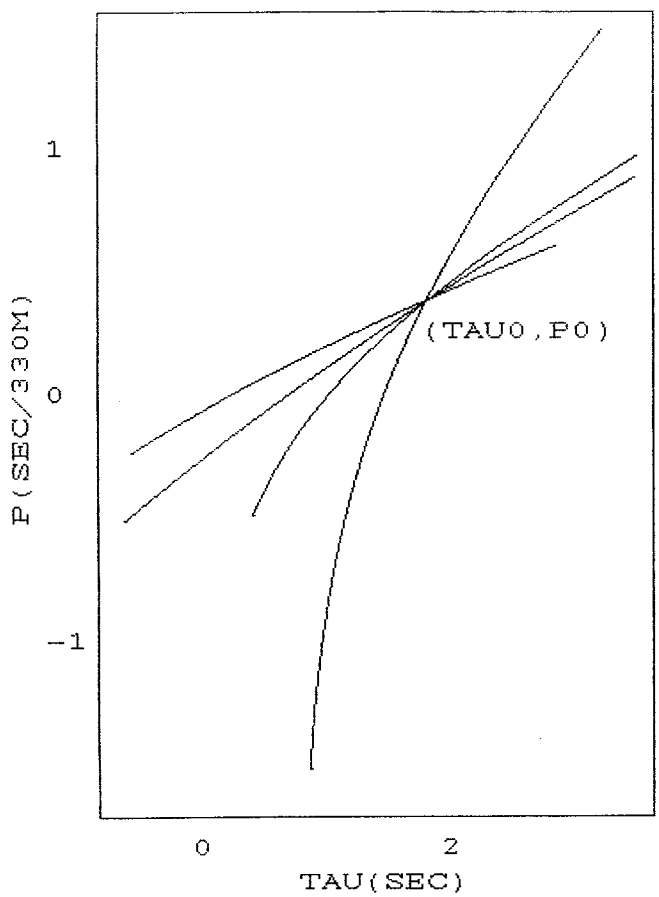

Figure 1b

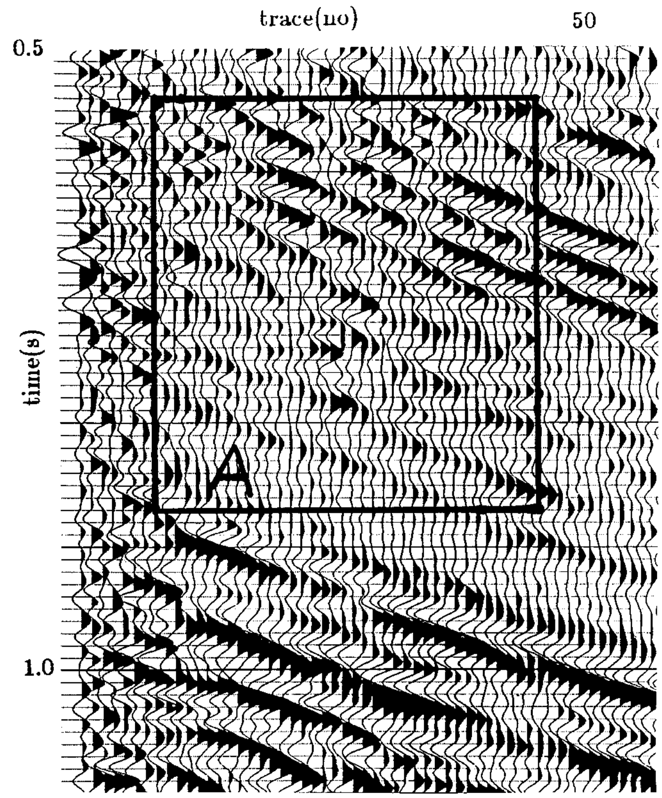

Figure 2b

Figure 1. Operators with multiple offsets. (a) Integral DMO — Operators are ellipses tangent to output linear event in Time-Space domain. (b) Radon DMO — Operators are intersecting hyperbolas in Tau-P domain.

Figure 2. Comparison of Radon DMO with conventional integral DMO for field data. (a) Stacked section without DMO. (b) Stacked section with conventional integral DMO applied before stack.

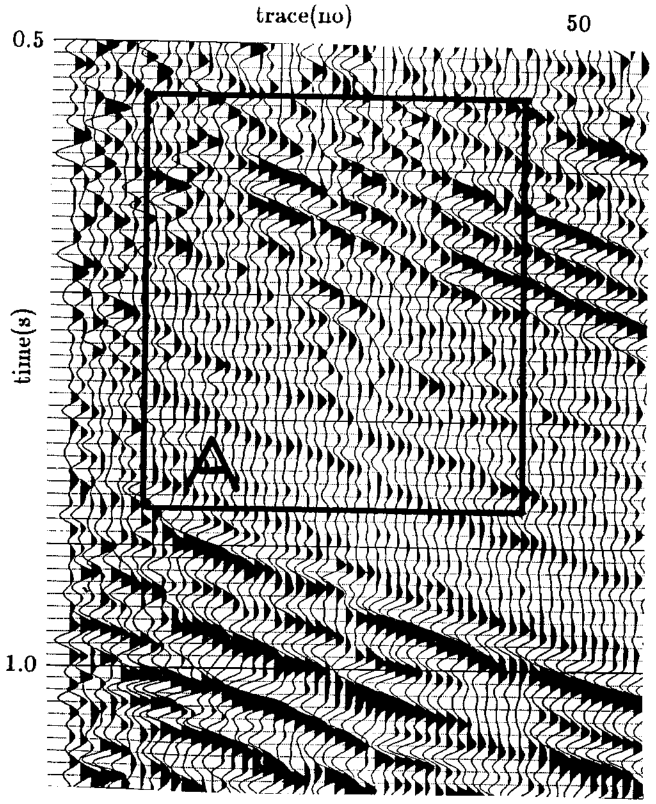

Figure 2c

Figure 2. Comparison of Radon DMO with conventional integral DMO for field data. (c) Stacked section with Radon DMO applied before stack.

under the integral transform when using data in multiple offset groups, as in Figure 1a. The only effect of irregular sampling on the Radon DMO is to alter the shape of the hyperbolas. Their intersection remains unchanged.

The Radon DMO method is not influenced if the input traces are from one offset, or multiple offsets, or are regularly or irregularly sampled. The results are correct in all cases. This is a major advantage of Radon DMO over other methods.

RESULTS

Figure 2 shows a field data example (one cross-line of a 3-D land dataset) with time from 0.5 s to 1.1 s with 33.5 m spacing between traces. All sections in this comparison were stacked using the same velocities. Figure 2a shows a stacked section without DMO. In Figure 2b conventional integral DMO was applied prior to stack. In Figure 2c the Radon DMO correction was applied before stack. When the section using Radon DMO is compared with the non-DMO section, it is apparent that continuity is improved, and the noise is reduced (see Block A, Figure 2). In comparing the Radon DMO with the conventional integral DMO section, it is apparent that the latter is affected by irregular input data sampling, as evidenced by some signal amplitude loss and apparent amplitude artifacts (Block A).

CONCLUSIONS

The Radon DMO method maps data directly from the NMO-corrected time domain to the DMO wavefield in the Radon domain. There are no aliasing problems for either regular or irregular data samples. In addition to DMO's function, the Radon transform is helpful for reducing interference and random noise. Proportionately greater improvement can be expected by using the Radon DMO when survey design and acquisition parameters yield very irregular sampling in offset. The method is practical and efficient, with computing costs comparable to those of conventional integral DMO methods.

ACKNOWLEDGMENTS

The authors express thanks to Dr K. Larner, C.H. Green Professor, Colorado School of Mines for reviewing this paper and advancing significant suggestions. Also, the author would like to thank President Mark Ziegler, Managers Curt Moran and Kevin Revels of Vector Seismic Data Processing, Inc., for supporting and helping this research work.

REFERENCES

Gelfand, I. M., 1966, Generalized functions: 5, Academic Press, Inc.

Hale, D., 1984, Dip-moveout by Fourier transform: Geophysics **48**, 741-757.

Hale, D., 1991, A nonaliased integral method for dip moveout: Geophysics **56**, 795-805.

Robinson, E. A., 1982, Spectral approach to geophysical inversion by Lorentz, Fourier and Radon transforms: Proc. IEEE, **70**, 1039-1053.

Ronen, S., 1994, Handling irregular geometry: Equalized DMO and beyond: Society of Exploration Geophysicists annual meeting at Los Angeles, Expanded abstract, 1545-1548.