3-D field design, migration, and aliasing

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ABSTRACT

This paper is a short comment on the field design and processing of 3-D data, related to common midpoint scatter within a 3-D bin. The concern is a loss of high frequencies that occurs in dipping events where the common midpoints are evenly distributed across the bin. One of the factor that must be considered in addressing this apparent problem is the loss of high frequencies that should occur to prevent aliasing of the dipping event. The contents may be controversial, and interesting debate may follow.

BACKGROUND

3-D land projects are designed with orthogonal lines of sources and receivers. The subsurface coverage results in a rectangular grid with dimensions of half the source and receiver spacing. Ideal acquisition on an ideal grid would allow the gathering of all common midpoints to centered within each bin of the grid. In practice, use may be made of earlier existing cut lines, or the source (or receiver) locations skidded to bypass physical obstacles. The resulting common midpoint (CMP) locations will not always fall at the center of a bin, but may be spread about the bin.

Recent articles, such a Perz 1995 and Gardner 1994, have evaluated the results of prestack migrations. Perz showed that different prestack migration methods gave results that varied with acquisition techniques. Acquisitions with CMP's spread within a bin produced different result for DMO with post stack migration, than with full prestack migration, that used accurate source and receiver geometry. This difference was not seen in acquisitions that forced all CMP's to be centered within the bins.

The difference between the DMO and full prestack migration was a loss of frequency content of dipping events, and is attributed to loss of resolution in stacking the traces within the bin.

The conclusion of these results may be interpreted that bin centering should be a requirement of 3-D design and acquisition, and/or that DMO and post stack migration is the same as full prestack migration.

An initial guess at the loss of high frequencies for the scattered CMP's would be the difference in two way travel times from a zero offset bin centered ray at the surface to the center and corner of the bin at a given time. Quick calculations show a time difference of micro seconds, which will have little filtering effect. What about aliasing and anti aliasing effects?

ALIASING CONCEPTS

The previous paper in this report (Bancroft 1995) reviewed may aspects of aliasing that occur in acquiring and processing of seismic data. Some of the points to note are:

- control of aliasing is a compromise between:
  - source and receiver intervals (which also relate to the costs)
  - range of dips
  - frequency content of the dipping events
  - amount of aliasing noise
- the frequency of dipping event can be limited to prevent aliasing
- a box car filter is an effective antialiasing filter
- "natural" anti-aliasing filtering occurs in common scatter point gathers
- Kirchhoff migration can migrate aliased dipping events to an aliased migrated position: the cost is extra noise
- the cut off frequency f_c to prevent aliasing, given the velocity V, trace spacing Δx, and the dip on the section θ, is evaluated from

$$f_c = \frac{V}{4\Delta x \tan\theta} . \tag{1}$$

FREQUENCY LOSS DUE TO MIGRATION ALGORITHMS

Examples in the above papers show a loss of high frequency energy on a dipping event after NMO, DMO and post-stack migration. This reduction in frequency is expected with the change in dip after migration. When the angle of dip before migration is α, the dip after migration β is found from the migration equation

$$\tan\alpha = \sin\beta . \tag{2}$$

The corresponding change is evaluated from

$$\frac{f_\alpha}{f_\beta} = \frac{\tan\beta}{\tan\alpha}, \tag{3}$$

where f_α is the unaliased frequency before migration, and f_β the unaliased frequency after migration. These changes should be an inherent part of all migration algorithms provided the input data is not aliased. If the input data is aliased, some migration algorithms can migrate the aliased input dip to a migrated dip with aliased frequencies defined by equation (3). Typical migration algorithms do not allow the aliased signal to be migrated, and convert the aliased signals into noise. Two exceptions are Kirchhoff and FK migrations that can be implemented to migrated aliased signals. Usually however, the Kirchoff algorithms that allow aliasing are written to achieve improved runtimes by eliminating the part of the algorithm that prevents aliasing.

If an alias preventing algorithm is used, the drop in frequency after migration will be more than anticipated from an alias permitting Kirchhoff migration. The difference in algorithms however is not necessarily the problem for our bin scattered 3-D as the

Kirchhoff algorithms appear to be universally used, and possibly with no anti-aliasing filtering.

A POSSIBLE EXPLANATION

The problem appears to lie in the *natural* filtering caused by the data as it spreads along the dipping event within each. Figure 1 is a cartoon representation of energy before migration, with points used to represent the time position of energy on the dipping event. Figure 1a shows the bin centered CMP case and b) the distributed CMP case. If the energy in Figure 1 is replaced by wavelets with the same width, the stacked traces in part a) will be aliased. Assuming there are sufficient CMP samples in the bin of Figure 1b, (typically the case after DMO), the smear of energy along the stacked traces will approximate a box car filter with width T_{box} given by

$$T_{box} = \frac{2\Delta x \tan\alpha}{V} . \tag{4}$$

The first frequency with zero amplitude f_{box} is given by the inverse of T_{box}

$$f_{ox} = \frac{V}{2\Delta x \tan\theta} . \tag{5}$$

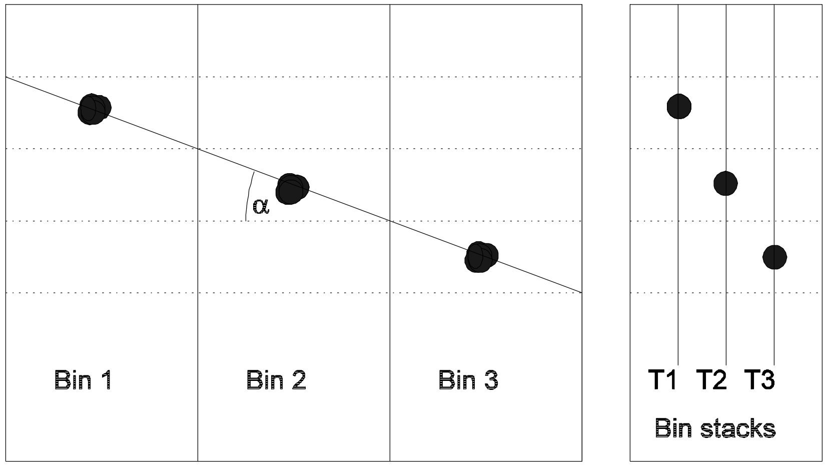
It is similar to equation (1) which defines the frequency limit for aliasing. Bins with random CMP positions will therefore have a *natural* partial anti-aliasing filter. The size of this filter is one half the size of a boxcar filter required to prevent aliasing.

COMMENTS

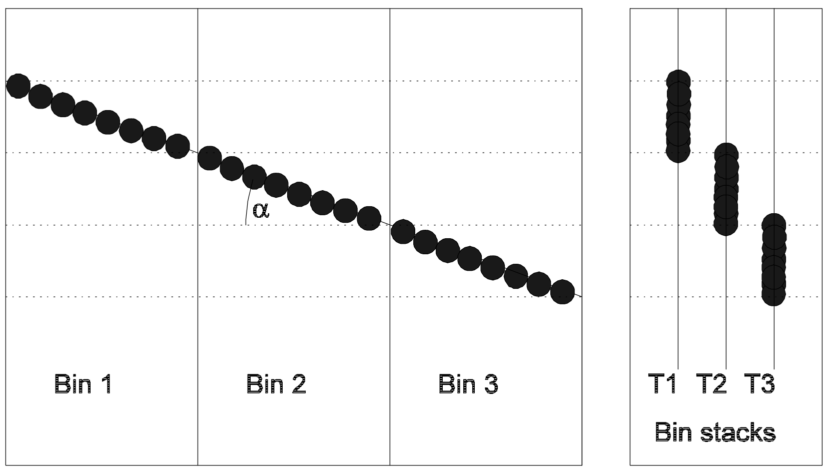
The *natural* anti-aliasing filter due to CMP bin smear should not be regarded as a detriment to processing, but as an asset to stacking as it removes higher frequencies that would appear as noise after migration.

3-D designs that force bin centering do not have the partial anti-aliasing filtering effects and can contain more aliased frequencies on dipping events than the CMP's smeared within the bin. These higher frequencies may provide an improved aesthetic appearance of the data, however, subsequent processing will contribute more aliasing noise to the migrated data.

It should be pointed out the many DMO algorithms move data in vertical planes between the source and receiver. These DMO'ed traces will rarely fall in the center of bins. Consequently, even if the 3-D projects are acquired with bin centering, the bin centering for CMP traces may be lost after DMO.



(a)



(b)

Fig. 1. Schematic representing traces on a dipping event spread across three bins, and three traces gathered from the bins, with a) showing the bin centered CMP case and b) the distributed case.

Kirchhoff migration does allow aliasing control, and can be designed to deliberately migrate aliased data at the expense of increased alias noise. This design however is usually used to reduce the run-time of the process. Designs that include anti-aliasing filters remove noise that may obscure other parts of the section (Lumley 1994).

The binning of CMP's is an intermediate step in the creation of a final migrated image. Designs based on the full prestack migration may reduce some of the current restrictions that are required to even out the fold in CMP bins.

CONCLUSIONS

The loss of frequency in dipping events found in some current field design tests could be an asset to the processed data as it helps eliminate aliasing noise. Field designs and acquisitions that force CMP bin centering may require re-evaluation.

REFERENCES

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