Combining acquisition & processing techniques to reduce ground roll on 3D land data

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ABSTRACT

The extension of the stack array noise reduction mechanism to 3D replaces the linear segment of the recording spread by a disk, the linear source and receiver arrays by square arrays, and the high linear density of source and receiver stations by high areal densities at a very high cost. Compromises are therefore necessary. This paper analyses their consequences on the filtering properties of 3D acquisition geometry associated or not with linear orthogonal source and receiver arrays. Various designs are compared before and after noise reduction in the FKxKy domain.

INTRODUCTION

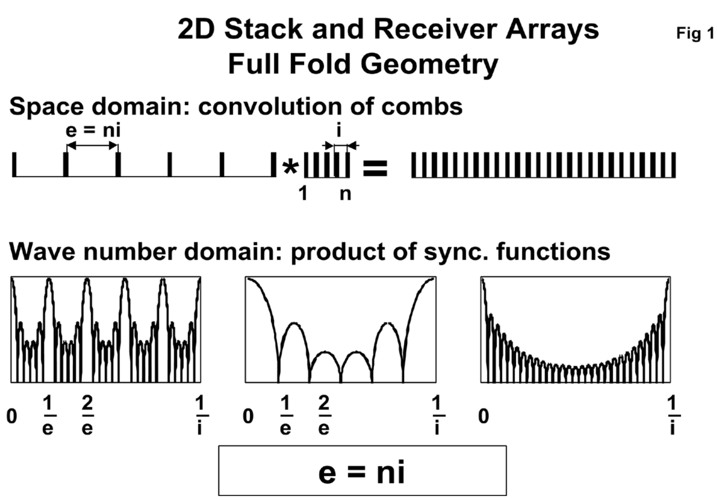
Acquisition and processing geophysicists must achieve two goals :

Improve signal-to-noise ratio.

Provide a faithful representation of the earth.

An important parameter in this process is the choice of recording geometry. In the last few years, many authors have discussed the relationship between acquisition geometry and imaging. This paper will focus on signal-to-noise ratio enhancement.

Most of us now agree that the 2D geometry question is answered by a receiver length equal to the group interval(1) : this array combination can be represented as the convolution of the aliased comb associated with the stack by the anti-alias associated with the receiver array (Fig 1).



This approach can be readily extended to 3D by replacing combs by lattices: the split spread becomes a disk, the number of recording channels and the SP and geophone densities rise to unreasonable levels (45000 channels, 400 SP and 40000 geophones / km2 for a station interval of 50m, a geophone interval of 5m and a radius of 3km). The aliased stack lattice is convoluted by the anti-alias geophone array lattice leading to an unaliased 3D stack array (provided the source and the receiver grids are shifted by half a grid step as in the 2D stack array), but its cost is likely to be a very powerful deterrent. For this reason compromises have to be found.

The first part of this paper discusses these compromises and describes the relationship between periodicity and variability of the offset and azimuth distributions. The second part is dedicated to a comparison between various designs.

PERIODICITY AND VARIABILITY

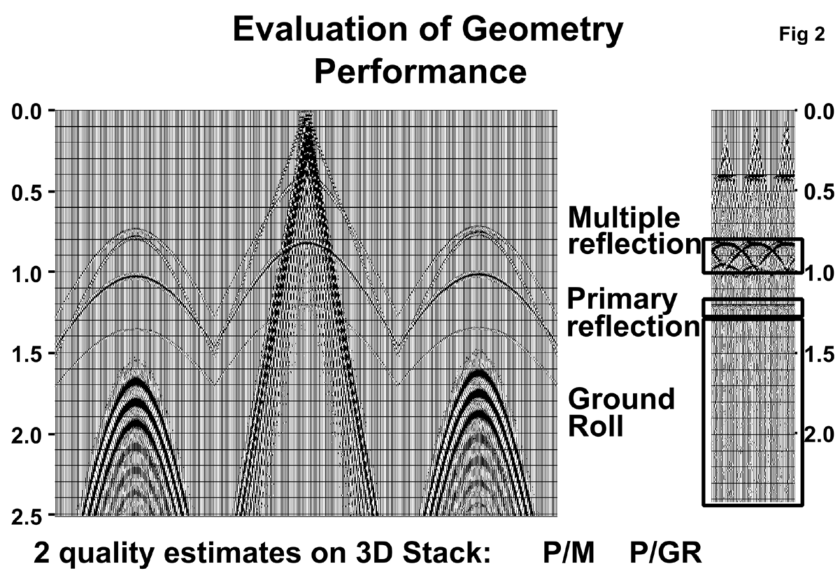
The most obvious compromise is a reduction in the number of source and receiver lines. This reduction usually makes 3D stacking fold lower than 2D stacking fold but it also generates a periodic variation in offset and azimuth distributions which makes the 3D bin stack vulnerable to aliasing.

Understanding the aliasing implications of this reduction is easier on a 2D geometry in which the SP interval is made a multiple (n) of the station interval : the offset distribution of each CMP can be represented by the convolution of 2 combs: One, common to all CMPs, with a tooth interval equal to twice the SP interval ; and the other associated with each of the 2n families of CMPs. This second comb has 2 teeth with a separation equal to an odd multiple (from 1 to n-1) of the station interval. The corresponding aliases will be found at wave numbers varying from 1/(n-1)e to 1/e. We therefore face an aliasing problem of which the variability
(difference between the shorter and the longer combs) and severity (number of aliases) is proportional to the SP interval. The 3D stack can be represented in a very similar way using lattices instead of combs. For a square stack lattice (same interval between source and receiver lines) the aliasing variability and severity are proportional to n^2. In the general case, they are proportional to the area of the grid cell defined by the source and receiver lines.

PERFORMANCE OF VARIOUS GEOMETRIES

To compare the performance of various designs, a flat geology model was used : it includes 2 primary reflections at 400 and 1200 ms, one multiple reflection at 800 ms and a radial noise (Fig 2). The quality estimate consists of both RMS amplitude averages and standard deviations computed after stack in various windows to reflect average residual noise and geometry imprint amplitude. For each geometry, 3 configurations were analysed:

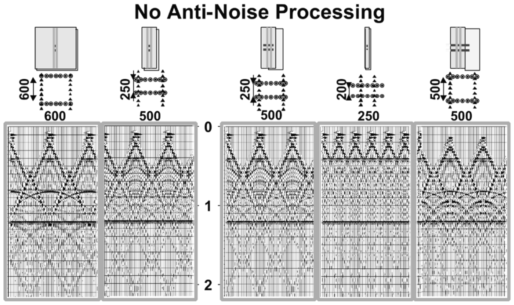
A. Point source and receiver without anti-noise processing.
B. Linear arrays without anti-noise processing.
C. Linear arrays with anti-noise processing.



The unconvoluted model constitutes a useful reference. Linear arrays have the important property that the convolution of 2 orthogonal linear arrays is equivalent to a rectangular array ; moreover, they keep operations simple. Anti-noise is often considered a major difficulty of 3D data processing. A particular algorithm may be more suitable for a given geometry than for another and therefore constitutes a possible bias. For this study, we have used a 3D FKxKy reject filter applied on a cross-spread decomposition of the geometry[2]. In this domain, the « cross-spread array » which is the convolution of the cross spread geometry by the source and receiver arrays is de-aliased[3] ; therefore, the efficiency of a FKxKy filter is optimal. Such a filter was used to attenuate radial noise and multiple reflections. All the geometries tested have in common the bin size (25*25m^2) and the receiver line length (6 km). All of them are symmetrical in both the in-line and cross-line directions. 3 patch widths (0.8, 2 and 6 km), 6 line intervals (from 100 to 1000m) and 3 lateral move-ups (1 line, half patch, full patch) are investigated. They are compared with the 2D full fold (60) geometry and the 3D full fold (3600) geometry. The results are summarised as follows: without anti-noise processing, noise amplitude depends almost solely on the size of the elementary cell comprised between source and receiver lines; neither the patch shape (square or rectangular) nor the swath overlap seem to make a significant difference (Fig 3). The use of linear arrays merely adds an extra 6dB attenuation. The effect of FKxKy filtering is more important : as should be expected on synthetic data, its attenuation is high but more interestingly, the dependency upon line intervals is weak (Fig 4).

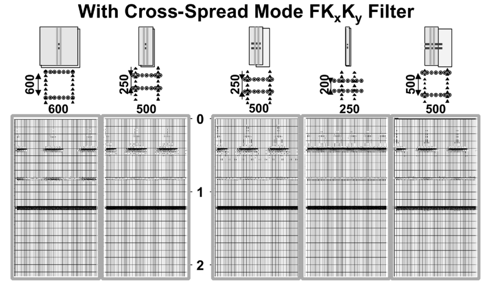
3D Synthetic Stack
Without Source and Receiver Arrays
No Anti-Noise Processing

Fig 3



3D Synthetic Stack
Linear Source and Receiver Arrays
With Cross-Spread Mode FK_xK_y Filter

Fig 4



CONCLUSION

Unlike in 2D, the reduction of ground roll cannot be satisfactorily achieved by the 3D stack by itself, except when the interval between source and receiver lines is reduced to the station interval. Linear arrays only slightly improve this reduction. On synthetic data, FKxKy filtering in the cross-spread domain can efficiently operate this reduction. With this process, the interval between source and receiver lines is no longer a critical parameter. It remains to be seen to what extent acquisition irregularities (geometry, coupling, weathered zone variations) can affect this result.

REFERENCES

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