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Multiple aliasing problems in marine data

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Abstract : Series of linear, steep noise have frequently been observed on post-stack marine data. Such aliased noise is closely associated with data acquired with large shot spacings, in our case mostly 3D data acquired with multiple sources and streamers. In many cases, the noise has been observed to penetrate the objective area of seismic sections and cause significant deterioration of the primary reflections. This paper reports on results of recent studies which have demonstrated that such noise is caused by aliasing of multiples. Some solutions are proposed.

INTRODUCTION

Most of the modern 3D marine seismic data has been acquired in a multi source and multi-streamer configuration resulting in a large shot spacing compared with that of the group spacing. For example, a group spacing of 25 m and shot spacing of 50 m were common acquisition parameters in SSB/SSPC and has been widely used elsewhere. In SSB/SSPC, it has been observed that linear steep aliased noise is inherent in the stack response of some 3D inlines in certain surveys. See line 3D-220 in Figure 1. This phenomena has been observed to occur with varied intensity depending upon certain geological conditions.

The same phenomena is also evident in deep water lines such as line DW-1 in Figure 2 which was acquired with a similar shooting configuration. In this case the aliased noise is clearly visible just below the long period water bottom multiple.

ACQUISITION PARAMETERS SIMULATION

To model the relation between the aliased noise and the acquisition configuration a reflected wavefront arriving from a shot to a receiver spread of 25 m group spacing was generated from a homogeneous layered synthetic model. The same shot was assigned with shot intervals of 25 m, 37.5 m and 50 m to simulate different shooting configuration. The datasets were then sorted to the CDP domain, NMO corrected using the primary events velocities and stacked. The results are shown in Figure 3. R1 (sea bottom) and R2 are primary reflections and M1 and M2 are sea bottom multiples of R1. Multiples M1 and M2 are seen to be less smooth and continuous for the stacks with 37.5 m and 50 m shot sampling. There appears to be a periodicity of 3 and 4 traces respectively for the 37.5 m and 50 m shot interval cases. This periodic line-up noise is termed as "aliased noise".

In Figure 4 we look at the respective stacks in the FK domain. As is to be expected, the aliased noise is mapped exactly on one half of the K Nyquist for the

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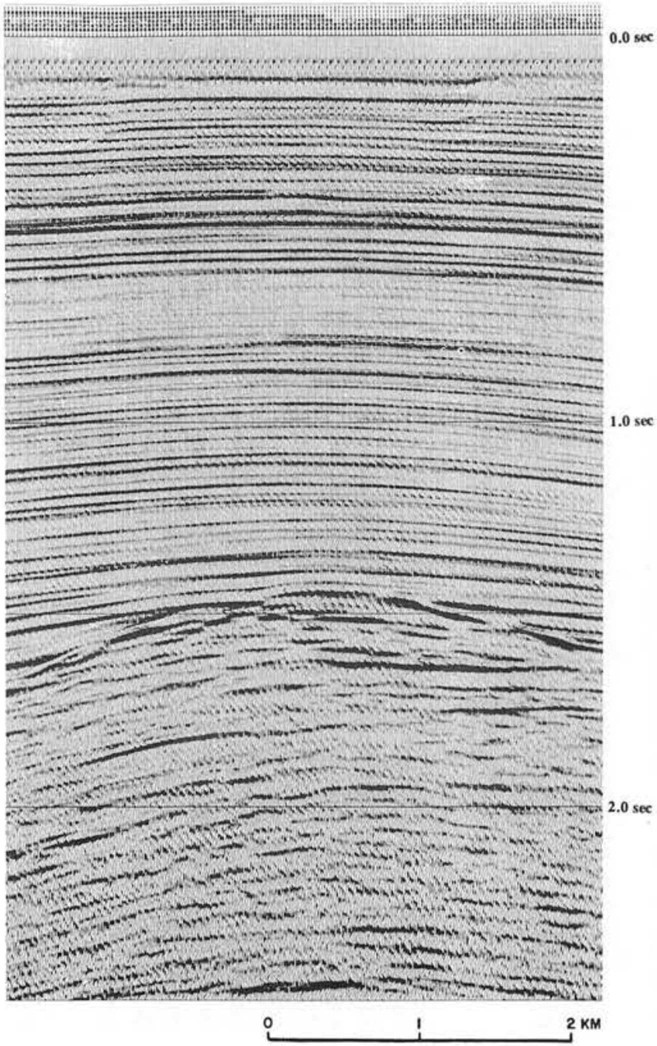


Figure 1: Line 3D–220 stack.

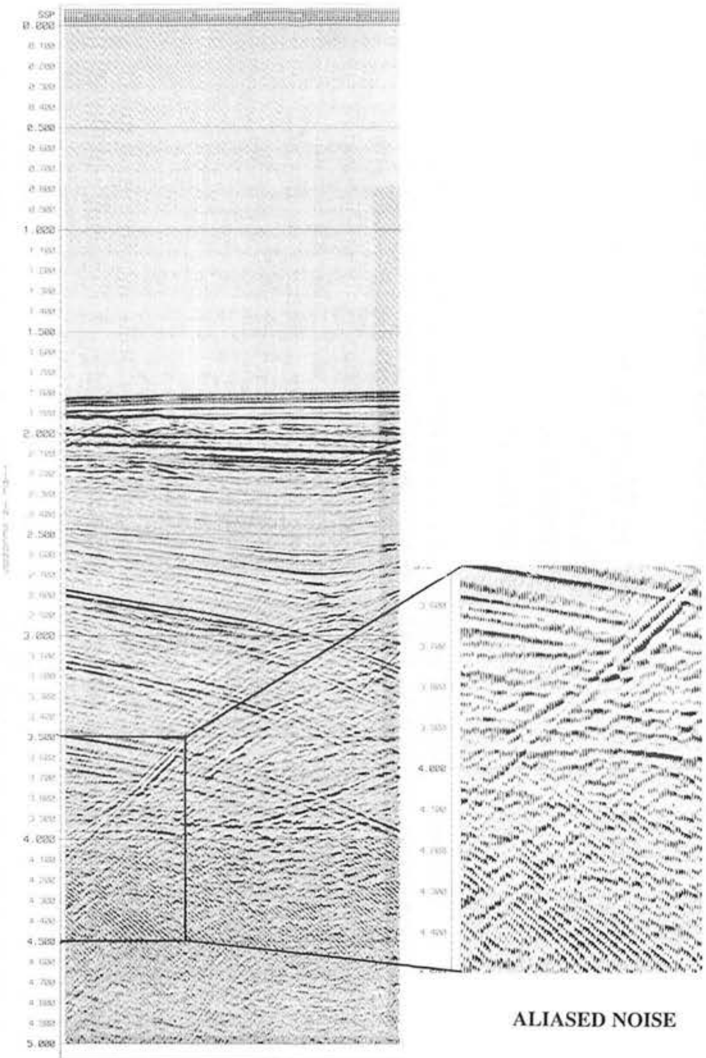


Figure 2: Line DW–1 stack.

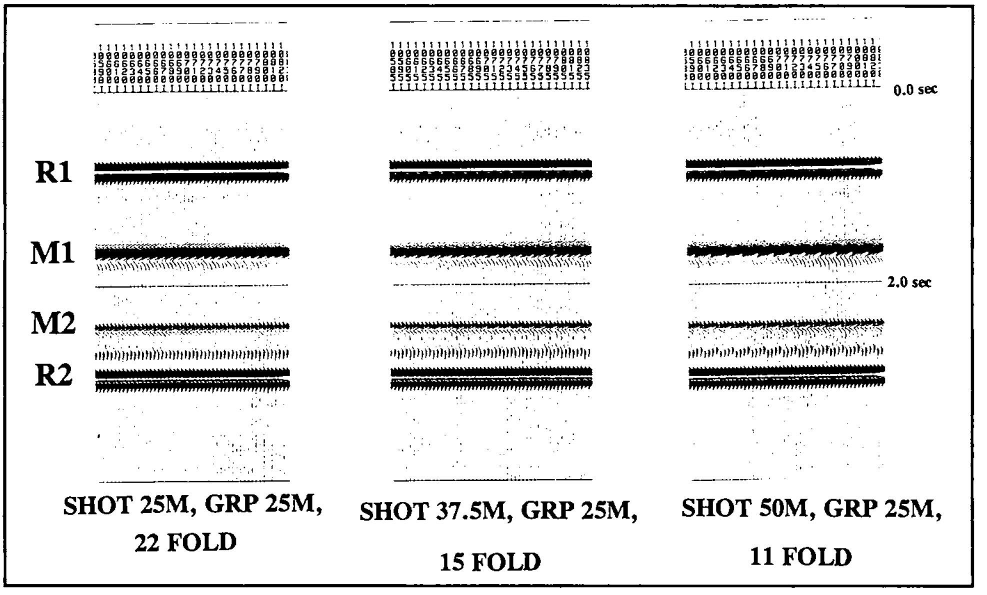


Figure 3: Synthetic NMO stacks.

stack with 50 m shot interval and two third of the K Nyquist for the stack with 37.5 m shot interval over a range of frequencies. In other words, the aliased noise is isolated at K = 1/shot interval. No aliased noise is visible on stacks with 25 m shot interval as this would occur at K Nyquist.

ANALYSIS OF MULTIPLE ALIASED NOISE

The synthetic data confirms our assumption that the aliasing noise pattern on the stack is related with the seismic acquisition configuration. Vermeer[1] (1982) has stated in his report the importance of correct sampling in the various domains. When the seismic data is reduced in multiplicity due to larger shot spacing (Figure 5 schematic diagram), undersampling in the CDP domain occurs. In the case of data acquisition with 25 m, 37.5 m and 50 m shot spacing and with 25 m receivers group spacing, the spatial sampling density in the CDP domain are 50 m, 75 m and 100 m respectively. Sampling intervals greater than 50 m in the CDP domain have shown to result in aliasing above 30 Hz. This is especially true for the case of multiples which remain uncorrected after NMO correction using primary velocities in the above modelling exercise.

The degree and intensity of the aliased noise associated with multiples depends rather strongly on the velocity of the multiples. To illustrate this point, CDP gathers with spatial sampling of 50 m and 100 m of a line are shown in Figure 6. Data at the far offset with large moveouts of an insufficiently sampled CDP gather (Figure 6b) appears to be less coherent than the same gather with sufficient spatial sampling. This is mainly related to the aliased multiples energy. During the stacking process the aliased multiple noise will not be stacked destructively as it maps back to the K=0 axis. This results in aliased noise on the stack.

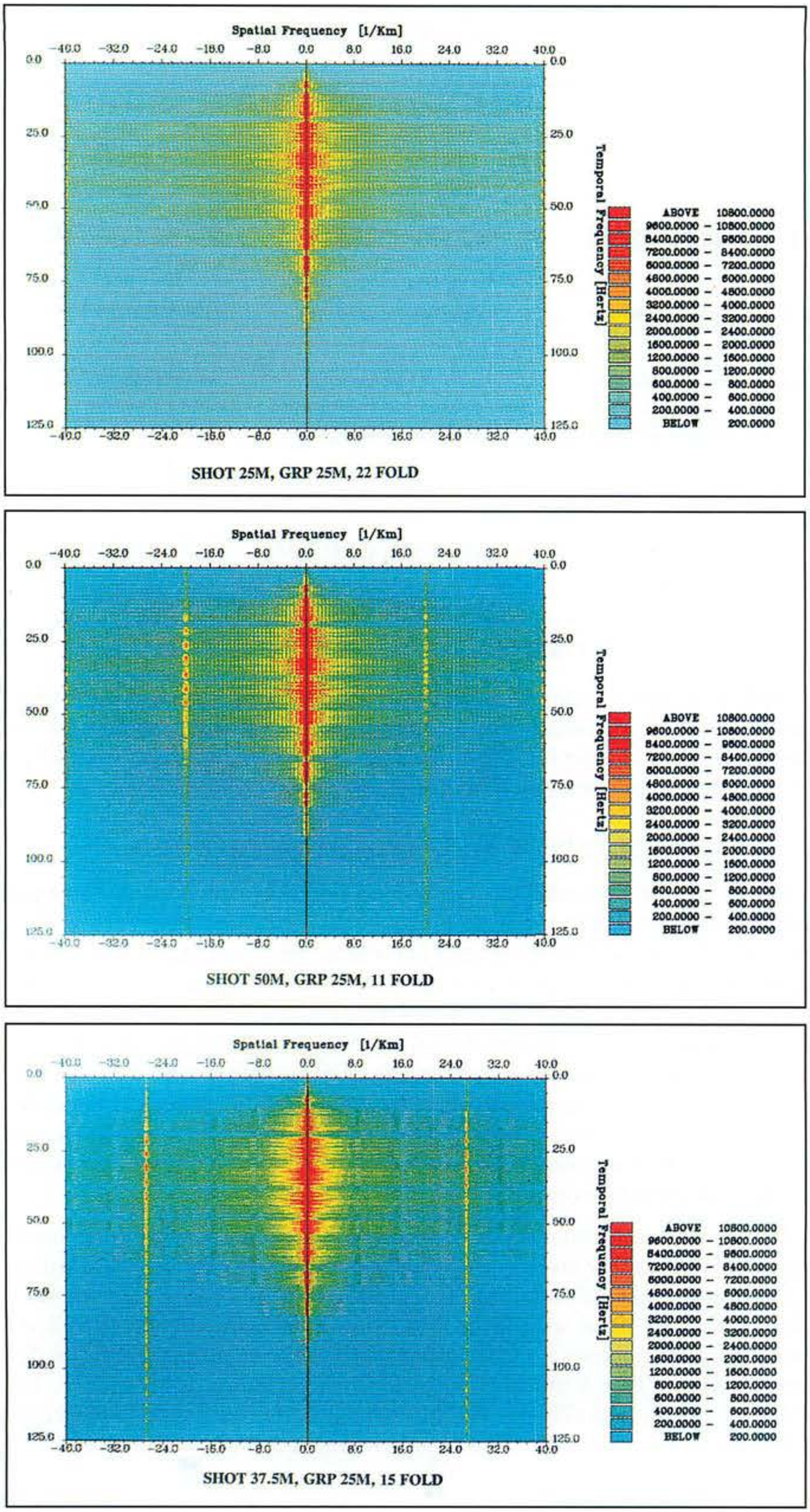


Figure 4: FK plots of the synthetic NMO stacks.

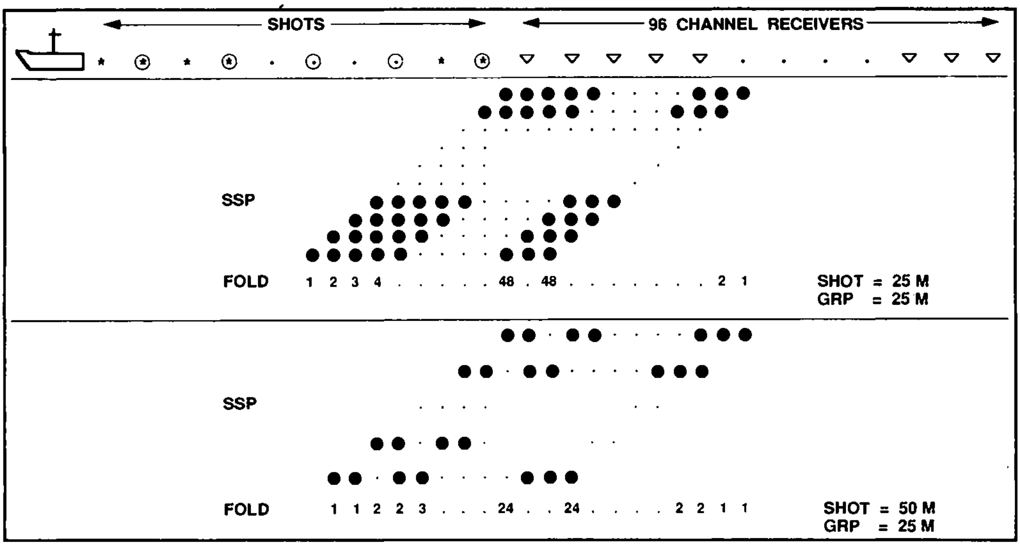


Figure 5: Schematic diagram of marine seismic acquisition.

MINIMISING THE ALIASING NOISE PROBLEM

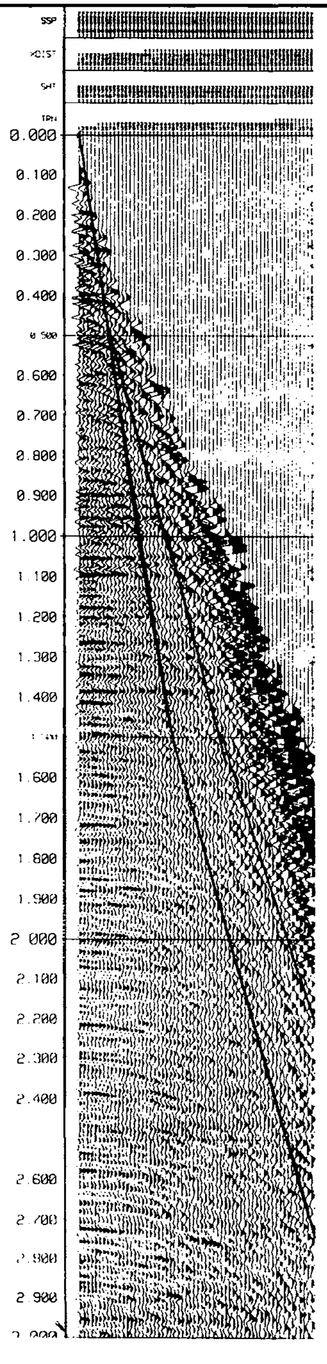
Pre-stack processing

In order to obtain sufficiently sampled CDP gathers in an already acquired field dataset, interpolation in the offset plane to substitute extra shots may minimise the aliased noise. However, interpolation programmes are not able to produce actual shots. Interpolation in the common offset domain is equivalent to a trace mix in the stack domain, effectively smearing the data.

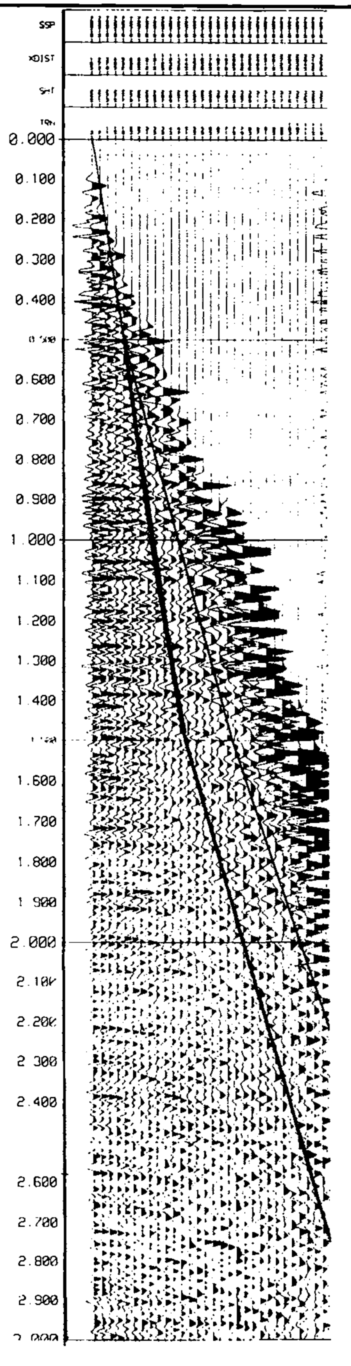
Since the far offsets of a coarsely sampled CDP gather contribute most to the aliased noise, a severe initial blanking of the gathers may help to improve the stack quality, but this may also deteriorate the quality of the primary reflections in the stack.

Removal of the aliased noise with shot domain FK filtering was another possibility considered. In fact, the noise with a velocity of 1500 m/s will alias in the shot domain at 30 Hz. As can be seen from comparison of Figure 1 with Figure 7, FK filtering removes most of the aliased noise. However, high frequency components of the noise can still be seen. The aliased noise is also coherent in the common offset domain. In conventional processing, the DMO process will tend to enhance the aliased noise as can be observed in line 3D-340 of the same 3D survey in Figure 8. The high frequency part of the aliased noise left after FK filtering in the shot domain has been boosted by the DMO process.

Multiple aliasing is particularly severe in deep water lines where the moveout of the water bottom multiples is large. Figure 9 shows the long period multiples below 3500 ms in the near offset singles of line DW-1. Figure 10 shows the stack of Line DW-1. As we know that the aliased noise is associated with low velocity



a) 50 m



b) 100 m

Figure 6: NMO CDP gathers with spatial sampling.

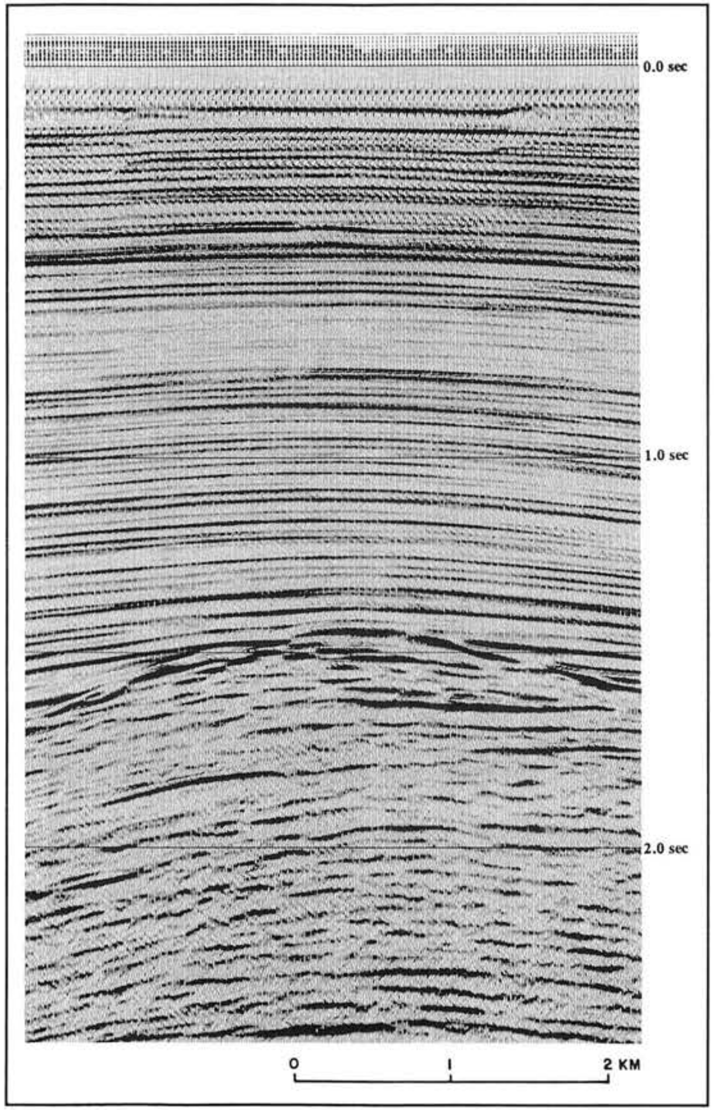


Figure 7: Line 3D–220: Stack with shot domain FK filter at 2000 m/s.

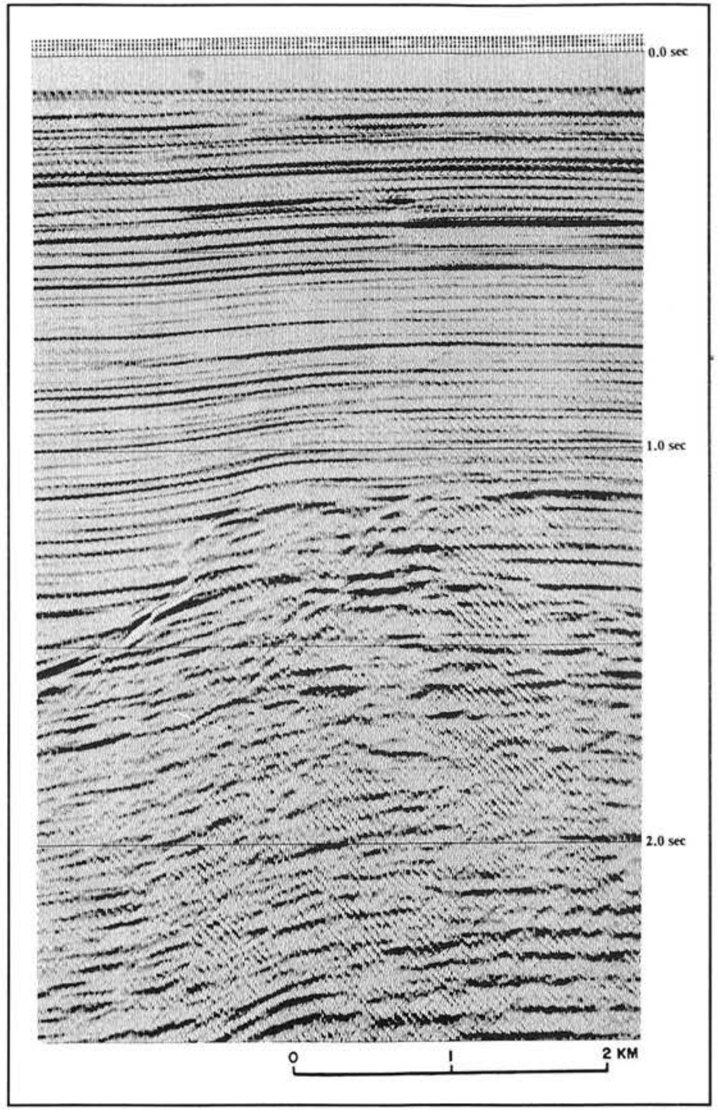


Figure 8: Line 3D–340: DMO stack with shot domain FK filter at 2000 m/s.

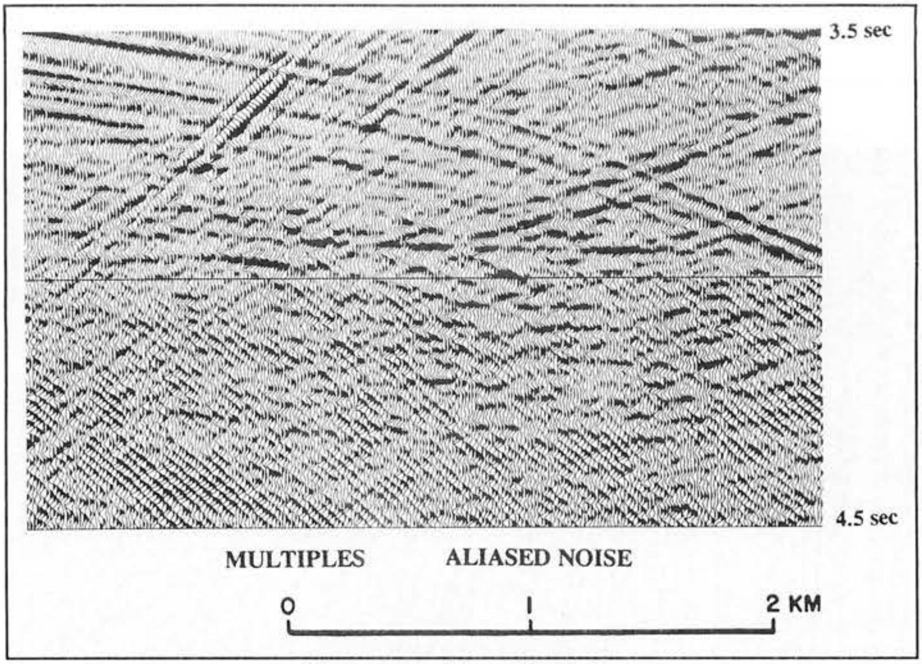


Figure 10: Line DW–1: Stack.

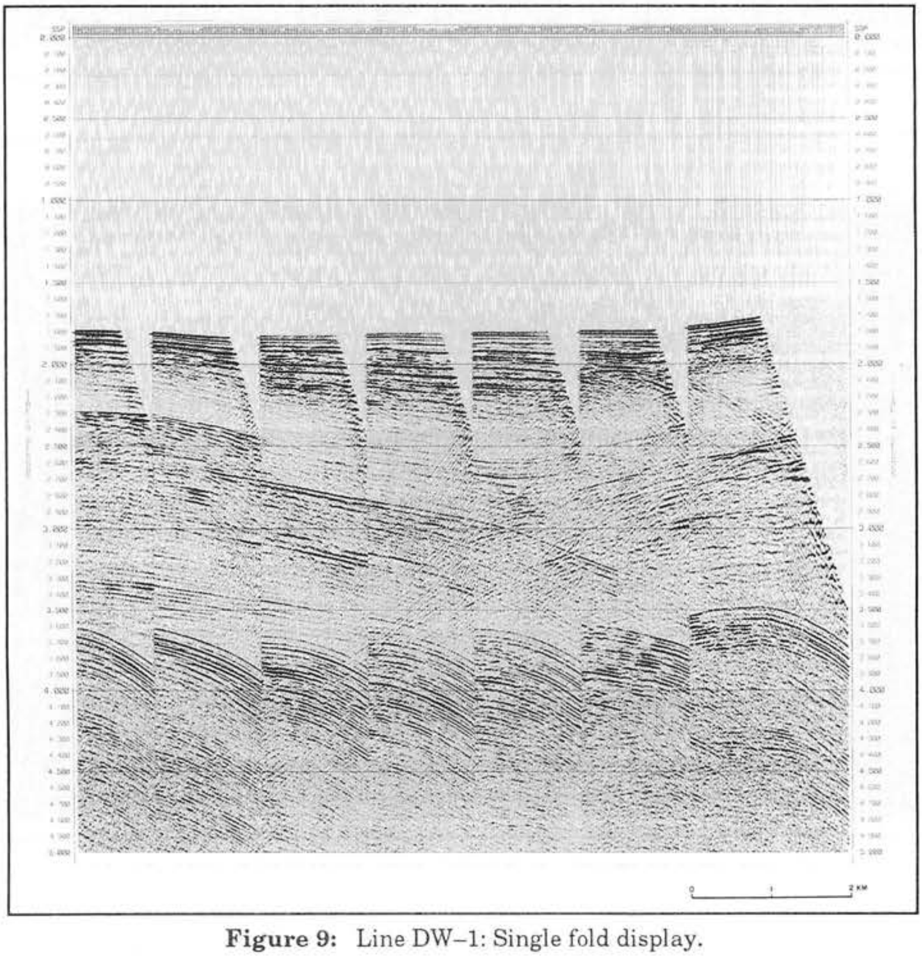


Figure 9: Line DW–1: Single fold display.

multiples, we expect that removing such multiples will not only meet our demultiple objective but will also remove the aliased noise altogether. A number of pre-stack demultiple techniques are available. They are in general computer intensive and hence expensive. One method of effectively separating and removing the multiples is in the U domain. Figure 11 shows the same singles with the multiples removed and the subsequent stack in Figure 12 shows the demultipled stack, free from multiples and aliased noise. The FK plots of the stacks with and without demultiple in Figure 13 shows the noise lobe at half K Nyquist effectively removed.

POST-STACK PROCESSING

Post-stack removal of the aliased noise is cheap but merely a cosmetic tool. When aliased noise is still present in the stack or migration, mixing the data post stack will attenuate the aliased noise to some degree but the data will be smeared, hence the lateral resolution of the stack will deteriorate.

From our study, it has been demonstrated that the aliased noise will map into a certain K value in the FK domain. Therefore, by applying a surgical tapered blanking operator (or rather a K-notch filter) centered around that particular K value in the FK domain, the aliased noise can be removed. Figure 14 shows the stack of line 3D-340 with the K-notch filter applied resulting in the removal of the aliased noise. This is a better filter than the trace mixing as the signal is better preserved but one ought to be very clear that the multiples are still not removed. The FK plots of line 3D-340 with and without post stack K-notch filtering are shown in Figure 15. Although the K-notch filtering has proven to be a good cosmetic tool to remove the linear noise, it has to be used with care in areas where severe dips are predominantly present as it might affect the high frequency component of the primary reflections.

CONCLUSION

Aliased noise in a stack section can be a multiple identifier. It is generated when slow velocity multiples are not properly stacked out owing to insufficiently sampled far offset traces in the CDP domain. The aliased noise pattern is directly related to the shots spacings with respect to the receiver stations spacings and occurs with specific seismic acquisition configurations. A dense shooting configuration resulting in properly sampled CDP gathers will prevent its occurrence.

In the event where aliased noise is present in the data, a surgical FK filter centered around the K value of the shot interval is a cheap and effective post stack method of removing the noise. However, in the case of dipping geology and even diffractions, such technique can affect the high frequencies of the dipping events.

The best solution for removing the aliased multiple noise would be to remove the multiples altogether prior to stacking the CDP gathers. However, most effective demultiple techniques are expensive.

The attenuation of the aliased noise would inevitably contribute to an improved migrated section.

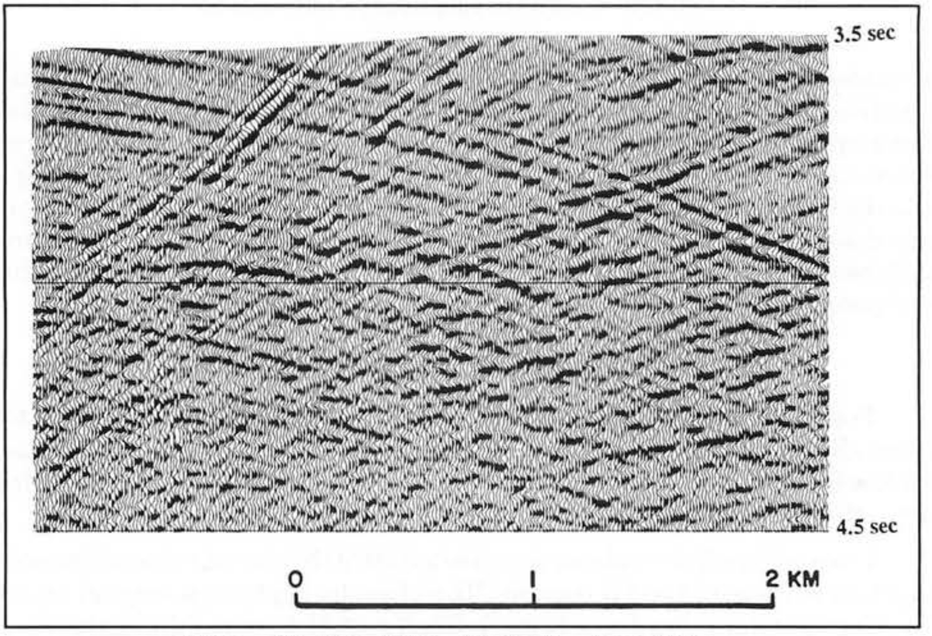


Figure 12: Line DW-1: Stack after demultiple.

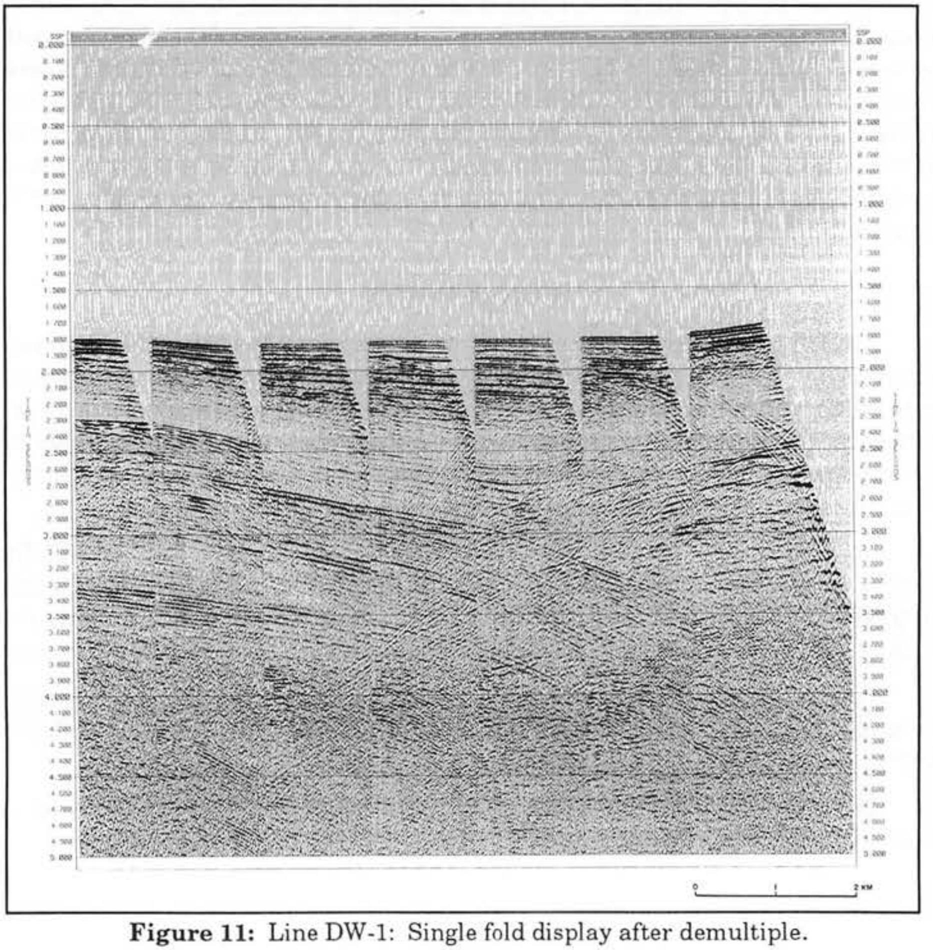
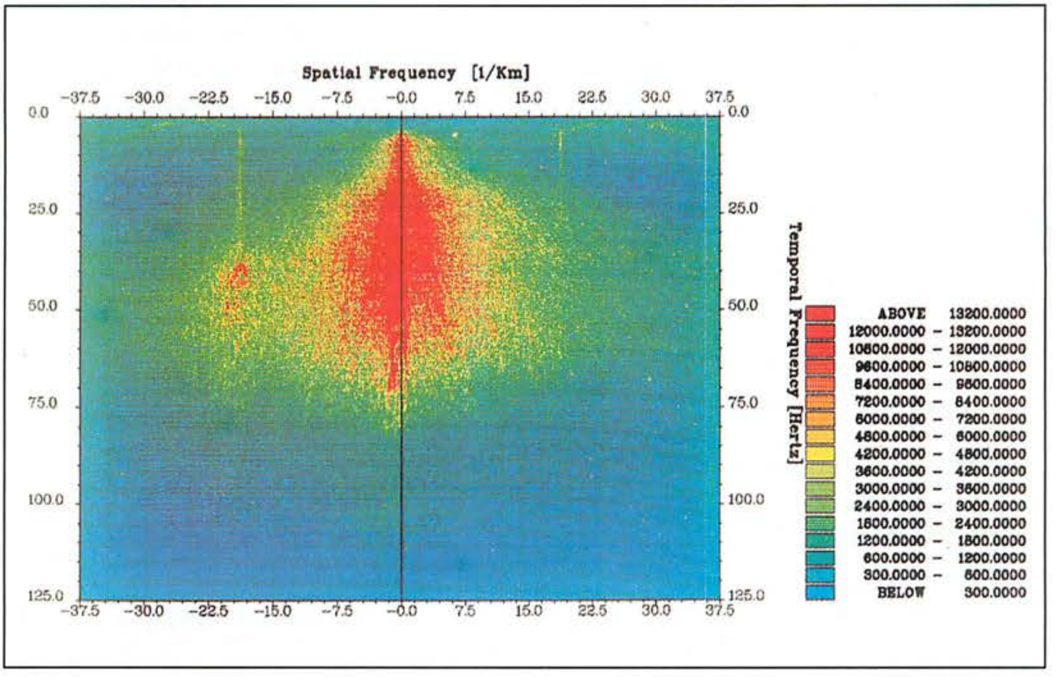


Figure 11: Line DW-1: Single fold display after demultiple.



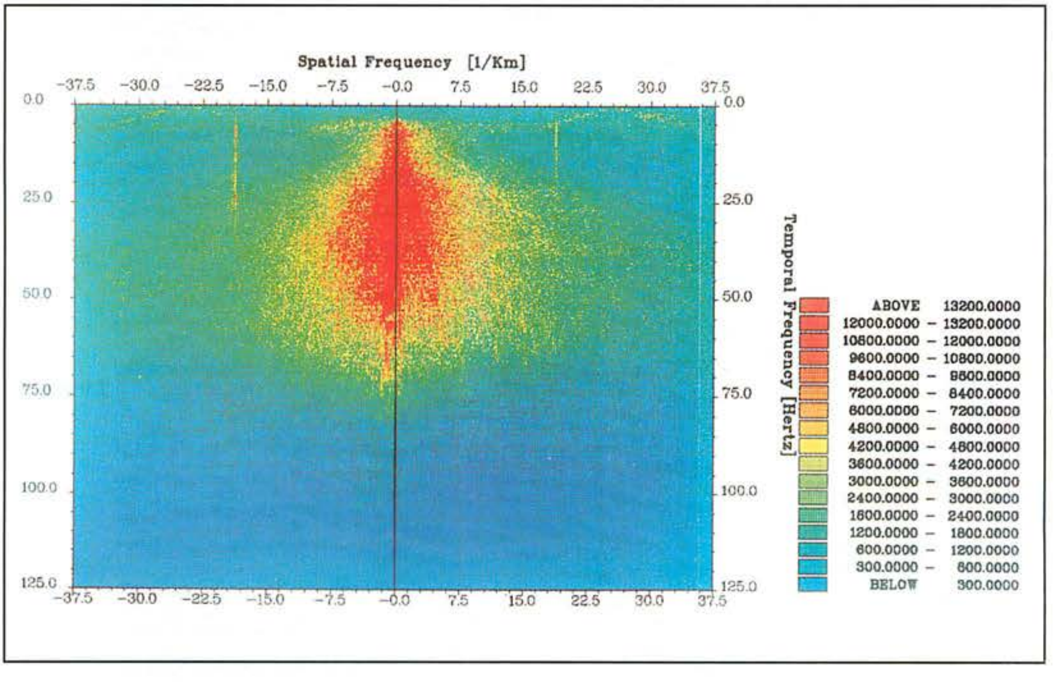


Figure 13: Line DW-1: FK plots of a) Figure 10 Stack, b) Figure 12 Demultiple stack.

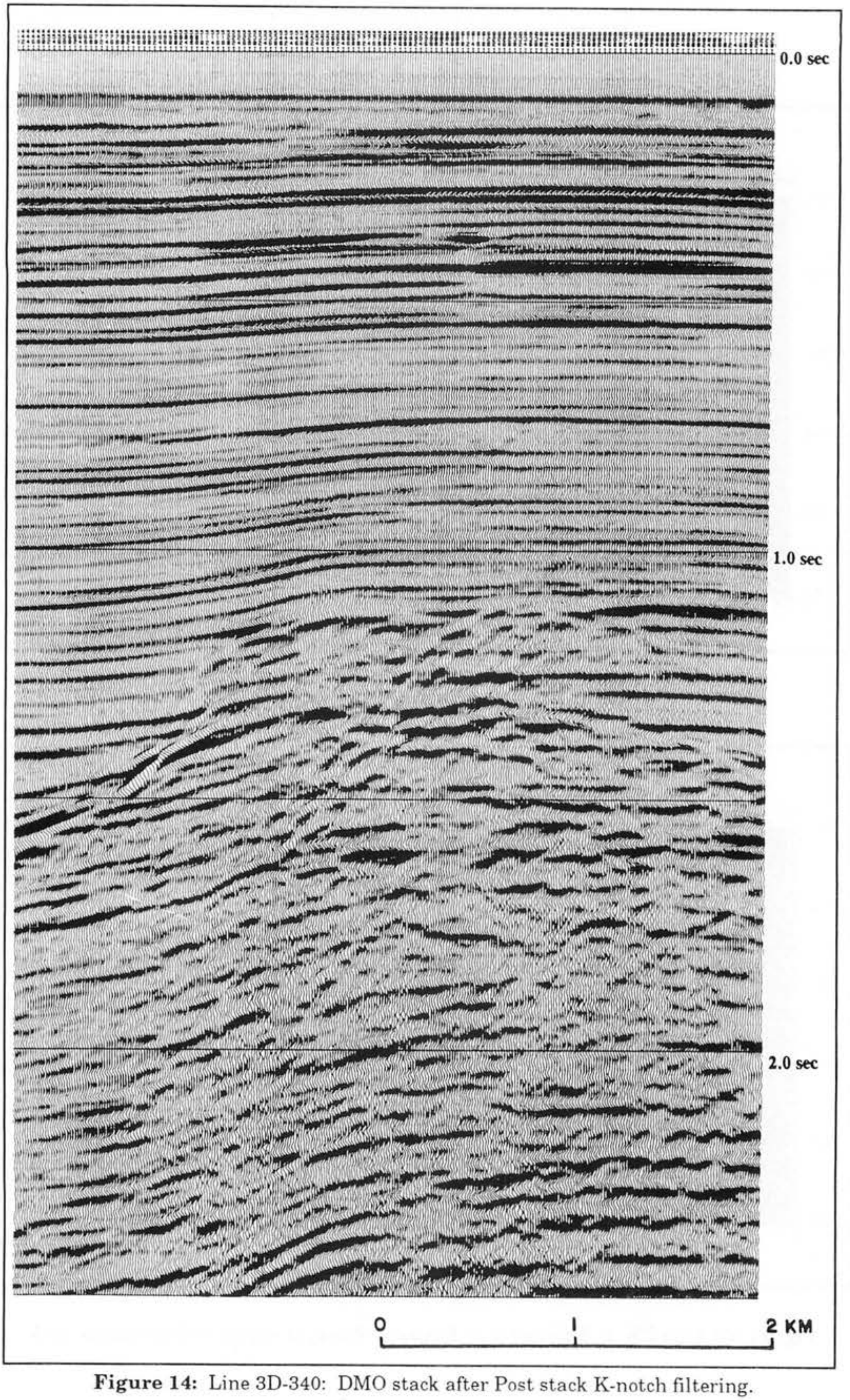


Figure 14: Line 3D-340: DMO stack after Post stack K-notch filtering.

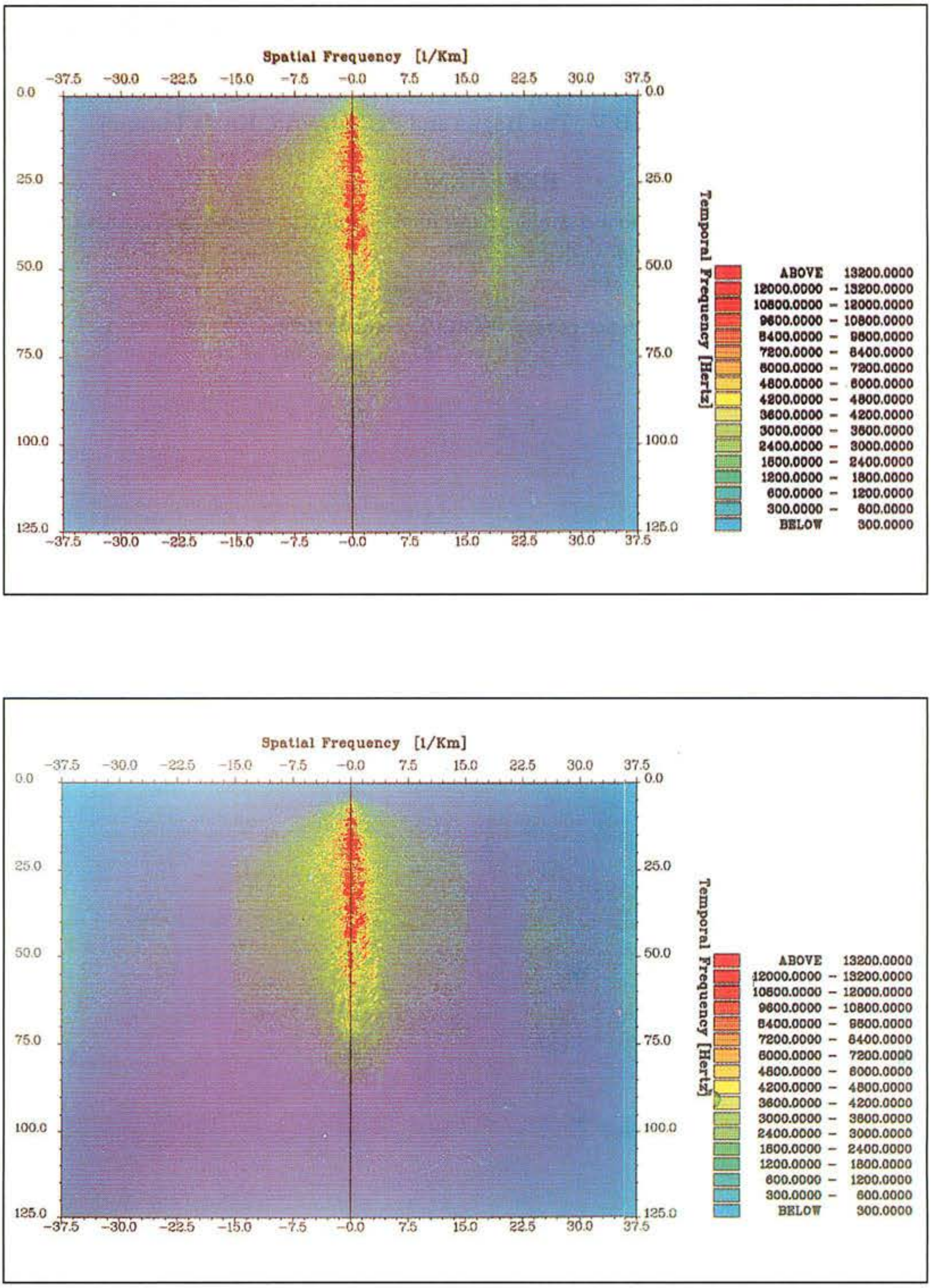


Figure 15: Line 3D-340: FK plots of a) Figure 8 DMO stack, b) Figure 14 DMO stack with K-notch filter.

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