Removal of Coherent Linear Noise without "Side Effects" and its Application to Pre-stack and Post-stack Seismic Data

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Summary

Elimination of coherent linear noise in seismic data is usually carried out with either F-K filtering or by radial trace transform, both of which involve transformation to another domain and back. This, however, introduces its own artifacts. In addition, F-K filtering suffers from aliasing problems and the strict requirement of uniform source-receiver offsets while accurate trace interpolation in the x-t domain is a must for effective filtering of linear noise in the transformed radial trace domain[1]. A new variant to the radial trace concept has been introduced recently[2] in which a ***local*** radial trace is constructed centered at each trace sample of a shot record along the direction intermediate between a fan-like zone defining the extent of the linear noise. The median of the sample values along this ***local*** radial trace spanning over neighbouring traces represents the linear noise at that trace sample point. The attractive features of this approach are (1) no transformation to a different domain is required and (2) a simple linear interpolation may be employed to generate local radial traces in case of missing data.

A software module incorporating this methodology has been developed in-house and successfully applied to remove linear noise for (a) proper pre-stack amplitude analysis and (b) improved stack response. ***A new feature of auto selection of the slope of a noise stream*** within a fan zone defined by two time values and the slopes of the linear noise at these times, has been introduced. This minimizes the number of passes required for filtering of noise and the need for precise measurement of their slopes at different time levels which may vary in different shot records over a seismic profile.

Introduction

The objective of the present work is to attenuate linear noises on seismic records through the technique of ***local*** **radial trace *median* filtering**[2] and to see its utility both at the pre-stack and post-stack levels.

Methodology: the local radial trace

The basic idea is to construct a "local" radial trace through each data sample spread over a few adjacent traces and oriented along the linear noise and use a median filter to model or extract the linear noise. This considerably reduces the missing data problem and, more importantly, avoids possible artifacts resulting from application of the conventional forward and reverse radial transforms (for details of radial transforms, see Ref.1). First, a fan-like area marking the zone of linear coherent noise is drawn whose origin $O(x_0, t_0)$ may or may not coincide with the origin (0,0) of the x-t plane (Fig.1). A local radial trace for one sample s(i,j) (j-th sample of the i-th trace of the input data) is part of a radial trace whose central sample is the original sample itself and that passes through the origin $O(x_0, t_0)$. v_1 and v_2 represent the velocity limits of the linear noise while t_1 and t_2 are the corresponding intercepts on the time axis. Simple geometrical considerations show that

$$x_0 = (t_2 - t_1) / (1/v_1 - 1/v_2)$$
$$t_0 = t_2 + x_0 / v_2$$
$$v_n = (x_n - x_0) / (t_n - t_0)$$

where vn is the apparent velocity of the local radial trace such that $v_1 > v_n > v_2$, x_n and t_n are the offset and time of the sample s(i,j).

With these parameters, samples of the local radial trace corresponding to sample s(i,j) can be obtained by a simple interpolation in the x-t domain using a few adjoining traces. Thus for a given offset x of a neighbouring trace, the corresponding time of the local radial trace is

$$t = t_n + (x - x_n) / v_n$$

More specifically,

$$t_{n+m} = t_n + (x_{n+m} - x_n) / v_n ,$$
$$m = -k, -(k-1), \ldots, 0, \ldots, k-1, k$$

where k can typically range between 3 and 9 (corresponding to a total of 2k+1, that is, 7 and 19 samples) depending on whether a conventional or a step-varying median filter is to be applied. The median value of these samples represents the linear noise at the sample s(i,j), provided the interpolated slope is oriented correctly with the direction of the noise. Continuing likewise for all the samples, one obtains the noise profile. Direct subtraction of the noise from the sample values gives the desired filtered output.

Operationally, the user is required to provide v_1, v_2, t_1 and t_2 from which the radial trace origin $O(x_0, t_0)$ is calculated. The values of t_1 and t_2 are not restricted by the trace length. They can be less than zero or greater than the trace length. As regards the apparent velocities, v_1 or v_2 can take negative values in order to take care of back scattering type linear noise, if required.

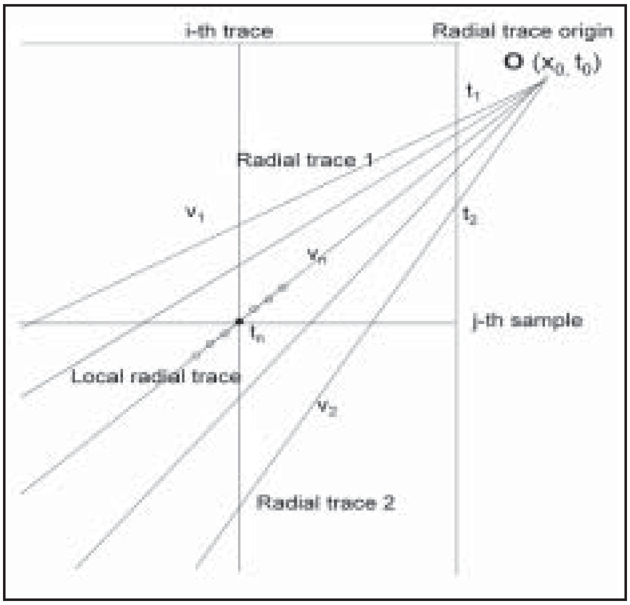

Fig.1

Software implementation

The software for elimination of linear noise by the above method was developed in-house and successfully applied on a series of shot records. It has generally been observed in various shot gathers that closely spaced linear noises rarely align themselves even within a single fan-like spread as shown in the real data example (Fig.2). Hence, a number of passes are normally required to filter out noises having very close apparent velocities. Also, it becomes cumbersome for the user to read out and supply the ranges of time and apparent velocity for each spread. To minimize the number of passes and the user input requirements, ***an additional feature has been added to the software***. An approximate range of time and velocity is input for each distinct fan-like region and then the software itself checks for the best local alignment at each sample point by allowing differential variation on the calculated gross slope.

Real data example

The application of the methodology and the software to real datasets is illustrated by Fig.2 to 4. Fig. 2a shows linear noise streaming right through a flattened PSTM gather. Removal of this noise has little or no effect on the stack in this particular case, since the coherent noise in adjacent traces tends to cancel each other. However, so far as the pre-stack data analysis like AVO is concerned, it is extremely important. Fig.2b displays the filtered data which facilitates proper AVO analysis while the removed noise component is explicitly shown in Fig.2c.

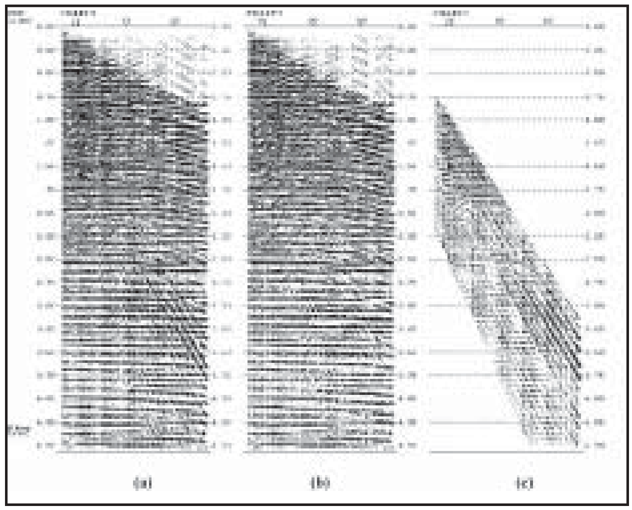

Fig.2

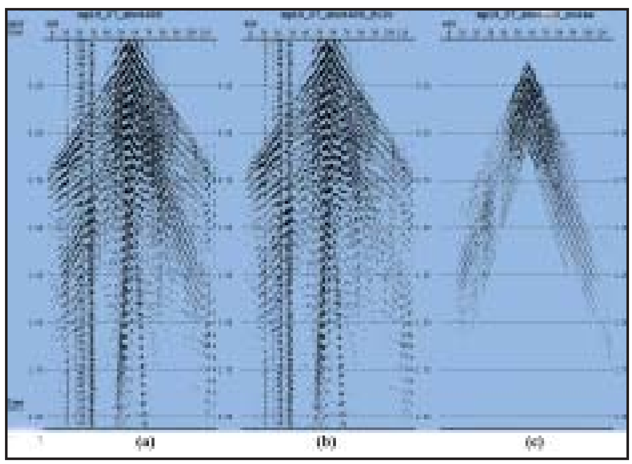

Fig.3

The effect of linear noise attenuation on stacked section is depicted in Fig. 4. Fig.3a shows a typical split spread field record containing strong ground roll from surface to about1700 ms. Reflection hyperbolas muffled in linear noise become clearly visible in Fig.3b. A close inspection

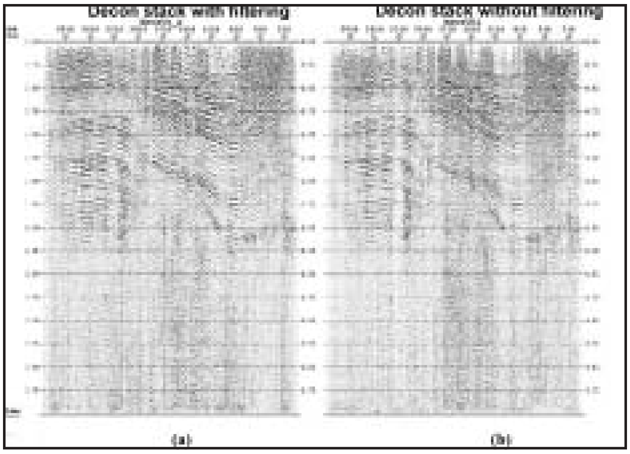

Fig.4

of Fig.3c shows noise streams of varying slopes within thedefined conical zone that is common for all shot records along the seismic line. The differential variations in the slopes are automatically taken care of by the noise removal software. The deconvolved stack responses of (a) filtered and (b) original unfiltered gathers are compared in Fig.4 with otherwise **identical processing steps leading to the stacked sections.** Overall improvement in the stack of the filtered gathers particularly in the clarity of reflectors above 1500 ms can be clearly seen.

Conclusion

A viable methodology and software have been developed to effectively tackle linear noises of any orientation present in a seismic record. The main advantages are (i) data transformation to a different domain and back are not necessary, (ii) missing data problem may be solved by simple interpolation and (iii) the method applies equally well to non-uniform offset distributions. Thus this procedure is suitable for handling similar noises in 3D data records as well where the offset distributions are not uniform.

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Views expresed in this paper are that of the aothor(s) only and may not necessarily be of ONGC.

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