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## Group array stack in high density seismic data acquisition— an attempt to boost signal to noise ratio

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### Summary

Land seismic API is a challenge in oil exploration to get the reliable subsurface image. Therefore it is essential to record and retrieve the signal with high fidelity for precise interpretation. The seismic signal from the subsurface is affected by high amplitude ground roll and ambient noise which is difficult to attenuate with conventional receiver array. Array has also an adverse effect on signal preservation in undulated field topography. Spatial aliasing is a well-known problem when sampling is inadequate for low apparent wavelength noise and signal. However, the seismic data acquisition with high density receivers has the advantage to sample the seismic wave field so that spatial aliasing effect is minimized and the group array stack methodology adopted in post-acquisition may bring out reflections contaminated with shot generated coherent and random noise in comparison to the conventional methods of seismic data acquisition. With the advent of high dynamic range and high density sensors acquisition systems it is practicable to enhance the signal to noise ratio for the delineation of geologic features with greater confidence.

An earlier study made with the methodology adopted using high density single sensors in data acquisition and preprocessing done such as group array formation (GAF) and group array stack (GAS) resulted increase of signal to noise ratio in shot gathers (A.Ojha et al. 2010,SPG conference and exposition, Hyderabad). This paper is an extension of study with an objective of assessing the efficacy of aforesaid methodology by shooting an experimental 2D line.

### Introduction

A conventional seismic exploration has the limitations for the delineation of deeper prospects and imaging subtle geologic features due to the factors like, improper spatial sampling, seismic data being contaminated with source generated noise and superimposed random/cultural noise etc. A conventional array design to attenuate high amplitude and dominant noise wavelengths may lead to missing of subtle geologic features in the stacking process. The intra array uneven topographic conditions also lead to further worsening of data in array effect. The improper wave field sampling in data acquisition may cause spatial aliasing effect which limits the faithful recording of high frequency signals from dipping reflectors. Therefore a close grid spatial sampling in seismic data acquisition and subsequent methodology is adopted in pre- processing which include high amplitude noise attenuation, group array base formation, estimation and application of intra array static corrections and group array stack. This may result increase

in signal to noise ratio and lead to better delineation of subsurface characteristics. The paper explains the methodology and its benefits.

### Experiment & analysis

An experimental 2D line was shot in Mandapeta west area of Krishna Godavari basin, India to study the efficacy of group array stack. Analog geophones were used with explosive as energy source. The layout of spread geometry comprises 5 sub lines (--SL) and each sub-line has 504 channels with a total of 2520 active channels per shot. Receiver spacing is 10m in a sub line and the sub line spacing is 5m (Fig: 1). A total of 213 shots with 40m shot interval was taken for the study.



Fig:1 The spread geometry in 2D line shooting.



The seismic data acquired with 40m (say) group interval and 10m receiver spacing are taken to study the effect of aliasing in wavefield sampling. Fig: 2 shows the FK spectrum of two sets of data (a) with 10m receiver spacing and (b) with 40m receiver spacing of one of the sub-line in a shot gather. The aliasing effect is minimized compared to 40m receiver spacing.

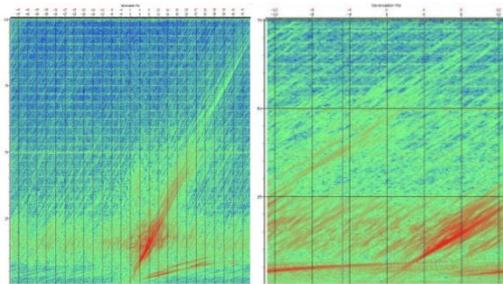


Fig: 2 (a) Fig: 2 (b)

Fig: 2 (a) aliasing minimized with 10m receiver spacing (b) noise and signal aliased with 40m spacing

In post-acquisition, the field data was processed to attenuate the high amplitude noise in frequency dependent amplitude domain and FK domain. The receiver channels in the shot gather was sorted and grouped into a pattern of 20 elements and group base of 30m as shown in Fig: 3 with the help of a suitable programme developed at the data processing center, ONGC, Chennai, called a group array formation (GAF) for each shot.

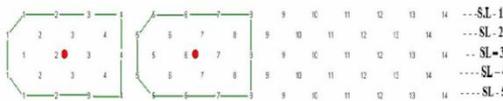


Fig: 3A pattern of group array formation with group interval 40m.

Field statics are applied on individual data channels to a reference datum plane (here MSL) to remove the effect of intra array near surface/elevation variations. The groups of elements are subjected to vertical stacking to obtain a single stacked trace corresponding to each group by which noise is attenuated. However, it is observed that the intra array elements have phase difference in signal standouts (Fig: 4a) due to the path difference from the shot point to the receivers which alters the signal waveform in stacking. Such differences in time were computed by cross correlation of traces in a time window of 100ms and these corrections are applied on the data which shows alignment of the waveforms in phase before stacking (Fig: 4b).

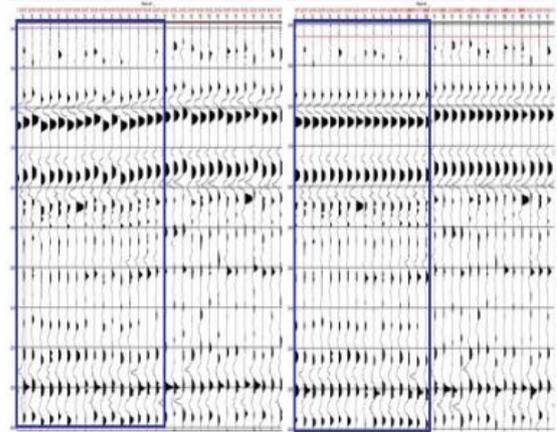


Fig: 4 (a) Fig: 4 (b)

Fig: 4 group elements of 52 & 53 (a) before intra array shift correction, (b) after correction

Group array stack of each group is a vertical stack to attenuate the random noise and thus brings back the reflections while preserving the signature of the subsurface with utmost fidelity. The center of energy in each group is assigned at 40m spacing marked in red circles (Fig: 3). A comparison of the shot gather with 40m group interval and the group array stack is shown in Fig: 5. In Fig: 5(a), the noise is prevalent whereas in Fig: (b), the same is attenuated considerably.

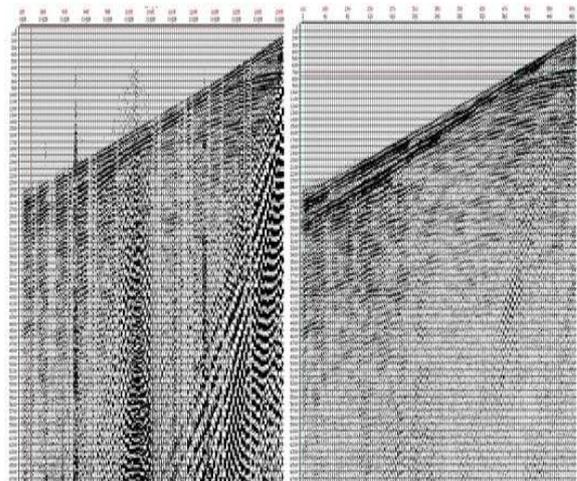


Fig: 5 (a) Fig: 5 (b)

Fig: 5 (a) conventional raw shot gather, (b) Group array stack shot gather



The group array stack was applied to all the shot gathers. The data of both the sets i.e. the conventional 2D of group interval 40m and group array stack data were processed up to post-stack migration by adopting identical processing sequences. The corresponding seismic sections show better the delineation of subsurface in group array stack (Fig: 6).

Fig: 6 Post stack migrated section, (a) conventional 2D, (b) group array stack

The zoomed portion of the sections between 2000-3000ms shows the better delineation of events in the group array stack.

Group array stack in high density seismic

From the high density shot gathers, different sets of group array bases are taken for the study to optimize the group array base. Fig. 7 (a), (b), (c) shows 3 different types of groups formed from the same set of data with group base of 10m, 20m, and 70m respectively. The corresponding post stack migrated section is also shown in Fig: 8 (a), (b), (c) respectively. As it is observed, with the increase of group base the attenuation of noise is better but the subsurface image gets smeared.

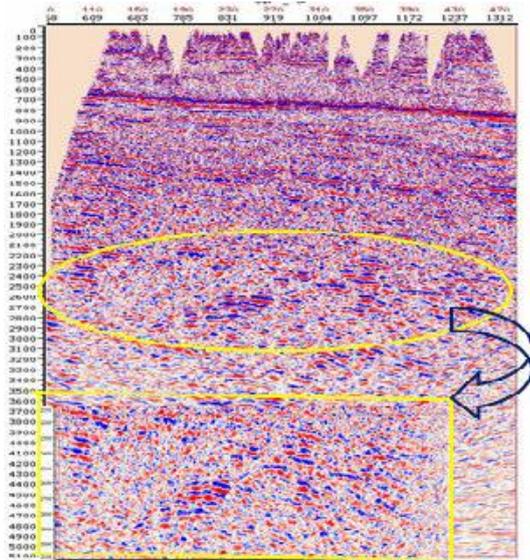


Fig: 6 (a) Conventional stack

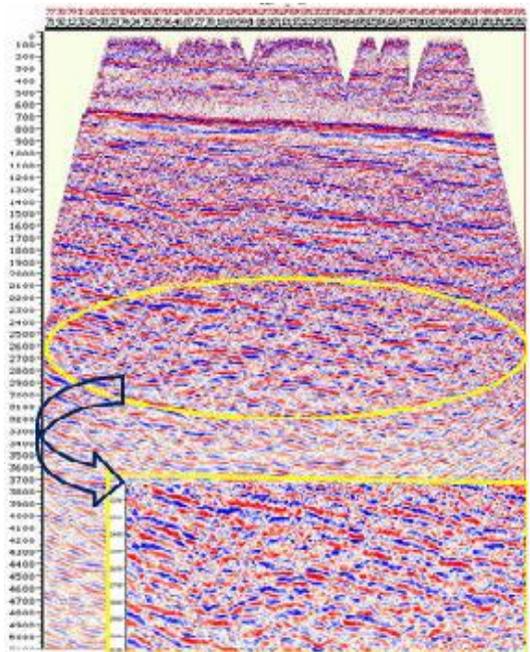


Fig:6 (b) Group array stack



Fig: 7 (a) 30m group base, 17elements



Fig: 7 (b) 10m group base, 7 elements

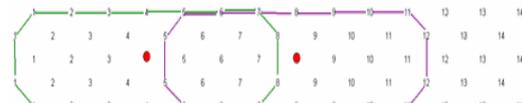


Fig: 7 (c) 70m group base , 37 elements

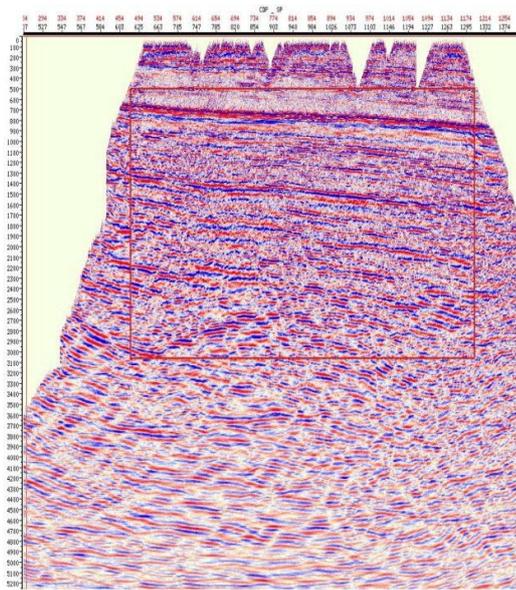
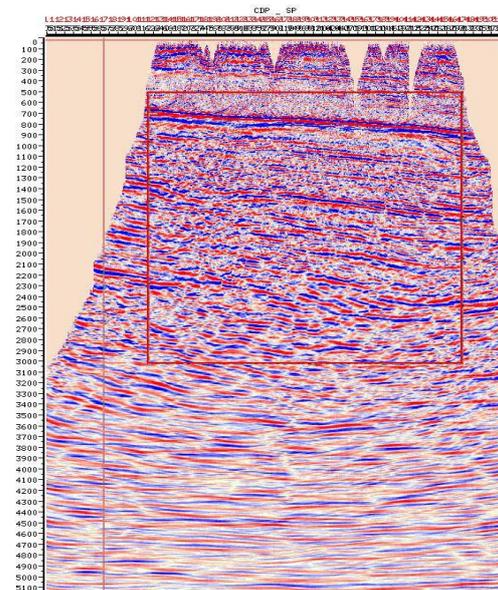


Fig: 8(a) post stack migration corresponding to 30m group base, 17 elements.



8 (c) Post stack migration corresponding to 70m group base, 37 elements.

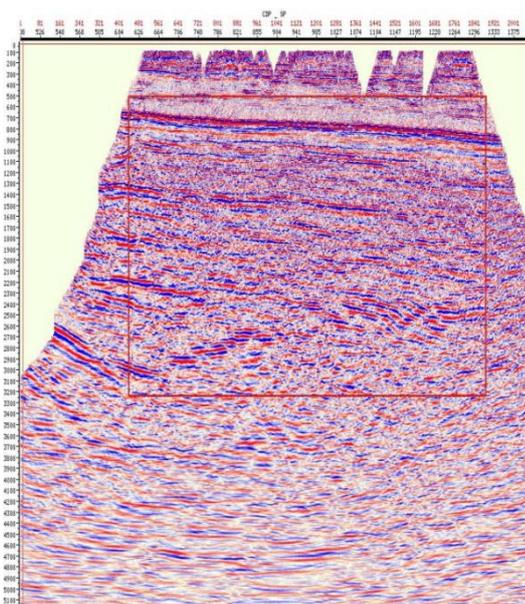


Fig: 8 (b) Post stack migration corresponding to 10m group base, 7 elements.

By choosing a longer group base the attenuation of noise is more but some of the structures delineated in 10m, 30m, 40m array base is lost in 70m array base. Therefore while acquiring data with longer array base, as sometimes adopted in conventional method to attenuate the high amplitude ground roll, the array removes some of the subtle geologic features. The choice of optimum group base formation depends on the objective and the subsurface to be imaged.

## Conclusion

Seismic data acquisition with high density receivers and the methodology adopted in group array stack can bring out the events dominated by noise without much alteration of seismic signal characteristics. Though the cost of acquisition is higher compared to conventional acquisition, the advantages of this method are that different group bases can be formed in post-acquisition from the acquired data set. This enables the choice of optimum group base to meet the exploration objectives. Further scope of study may be tried with dynamic geophone element mixing in group array formation i.e. the sorting of a variable number of group elements as a function of record time in making a group array stack which may lead to better frequency content in shallow events and noise attenuation in deeper levels.



This technology may be implemented in three dimensional seismic data acquisition where the in line and cross line noise which approach the layout of receivers from the shot line in different azimuths, can be substantially attenuated in group array stack there by imaging the subsurface with better signal to noise ratio. The intra array statics comprising the field statics and difference time shift corrections within the group base which is applied in post-acquisition enables the seismic signals being stacked in phase. Thus the seismic signature of the subsurface is retained to study the lithology characteristics, porosity and subtle geologic features for the exploration of hydrocarbons.

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