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Looking deeper through Pre Amplifier gain – A study

C.V.Jambhekar*,** *DGM (S)* & ***Paparaju Buddhavarapu, *CE (E&T), ONGC, Vadodara, India*

Summary

This article is a report on the experimental study carried out by the authors in Gujarat area of India. The experimental study was carried out to study, understand, analyze and design a methodology for proper utilization of Pre amplifier Gain feature of Scorpion^R seismic data acquisition system manufactured by M/s ION Geophysical Corporation, USA.
Note: The views expressed in this article are those of the authors only.

Introduction

A gain which is applied to seismic data and which is constant throughout the record length is called Pre Amplifier gain and is also represented as K Gain.

Scorpion^R seismic data acquisition system provides pre amplifier gain in four steps for systems with Geophones as sensors. For systems with SVSM^R as sensor (3 component sensor) the concept of pre amplifier gain is not applicable.

The Scorpion^R system has the provision to apply K gain (preamp gain) in two types: Fixed and Radial with respect to shot point.

Different preamplifier gains have different dynamic ranges and the capability of the system to record seismic data varies as shown in Table 1 below:

The four gain steps are G0 for Unity gain, G2 for 12 dB gain, G4 for 24 dB gain; G6 for 36 dB gain.

Scorpion^R system Analog Gain factor Vs Largest and Smallest values written to SEG Y tape.				
Gain Factor	Largest Absolute Value written to tape (mVolts)		Smallest absolute value written to tape other than zero (only LSB on) peak (mVolts)	Ratio of largest value to min value (peak)	Instantaneous Dynamic range of system as per system specification sheet with non shorted input
	Peak	rms			
0	2500	1768	0.000 310 462 589 257 994	8052.5	130 dB
2	625	442	0.000 077 615 647 314 499	8052.5	129dB
4	156.25	110	0.000 019 403 911 828 625	8052.5	121 dB
6	39.0625	27.6	0.000 004 850 977 957 156	8052.5	110 dB
Table 1: Input amplitude values of seismic data to Scorpion^R system					

E-mail: cjambhekar@rediffmail.com

Different preamplifier gains have different dynamic ranges and the capability of the system to record seismic data varies as shown in Table 1 below:

The maximum and minimum signal amplitude values depend on the preamplifier gain factor used during recording, as shown below in Table 1. The ratio of the maximum to minimum signal in each gain range is the same. Thus in effect, when the Gain value is increased, the system changes the range in which it records the data i.e., the range of A/D convertor is changed.

As gain is increased, instantaneous dynamic range for non shorted input decreases. Say if Gain G6 is used, the dynamic range is only 110 dB.

Figure 1 shows the shift in the range of the input signals to Scorpion[R] seismic data acquisition system graphically.
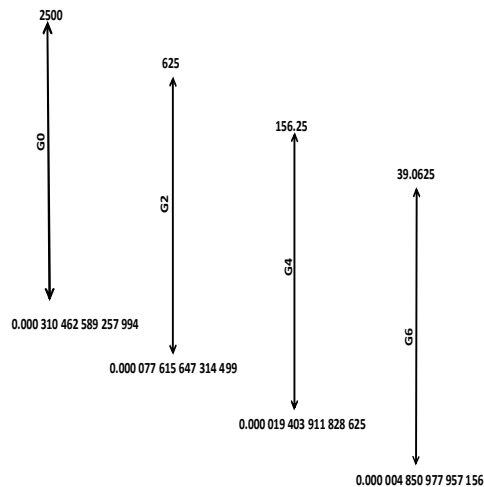

Fig 1: Graphic view of Gain values in mvolts

The preamp gain factor of each and every trace is stored in byte 202 of the corresponding trace Header. See Figure 2 for a sample shot of the trace header with each and every gain marked in byte 202.

Fig 2. Value of Gain in Byte 202 of Trace Header

Analog data from Scorpion[R] system is normalized to its equivalent input voltage, expressed in milli volts (mV). This means that whatever gain is applied to the data during recording is also removed before writing on the media tape and/or hard disc. If observer wants to compare the data with different preamp gains on a paper record, it will be difficult for him to do so as the gain is normalized. Also as we move from gain G0 to G6, system adds and preserves only those amplitudes which are critically low and cannot be observed on paper record as monitor record has very limited dynamic range.

With the application of higher preamp gain the smallest signal which is below the A/D converter range in the lower GAIN value will be brought within its range allowing the system to record the weakest data. It can be inferred from table 1 shown earlier that as we move from Gain G0 to G6 the upper amplitude limits falls from 2500 mV to 39.0625 mV with corresponding further decrease in LSB. Hence it is desirable to assess the average input amplitude levels to Scorpion[R] system to

arrive at correct Gain setting. Whether the data which is acquired with higher Gain setting contributes to higher Signal to Noise ratio has to be assessed by comparing this data with the cultural noise prevalent in the acquisition area.

Removal of actual gain applied before recording means that seismic data that is submitted to Processing is without gain. So, this Preamplifier gain can be dynamically varied across different terrain to capture weak seismic signal, as long as cultural noise prevalent in that area does not mask the seismic signal.

The Scorpion^R system provides Fixed and Radial Preamplifier gain settings options. In Fixed Gain Mode all seismic channels in the entire spread are applied the selected Gain of G0, G2, G4 or G6.

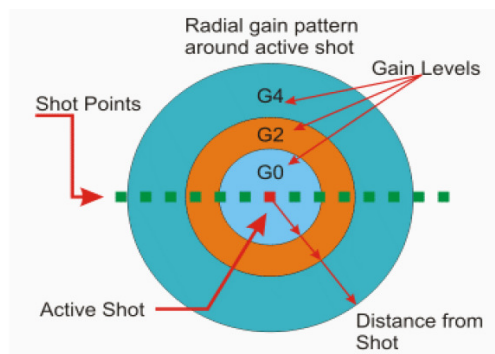In Radial Gain mode, Gain G0 to G6 is applied in a radius centered at Shot point as shown in Fig 3 below:

Fig 3. Iillustration of the Radial K gain application

In the figure 3, Gain after G4 by default will be G6.

Experiment Conducted

An experiment was conducted in Gujarat area with the following objectives:

1. Optimization of the Charge for a given area

2. Optimization of Pre amplifier gain settings of the Data acquisition system

This will help the observer in having optimal settings for data acquisition, not losing either maximum or minimum signals over the entire record length.

Before start of the above experimental work an experimental uphole study in the area was conducted to arrive at an optimum depth (OD). After careful study of the up hole data, conclusion was drawn that OD at the uphole site was 22m. Once this OD was fixed, Charges from 1.5 Kg , 2.0 Kg , 2.5 Kg for charge optimization were planned to be used.

After carefully studying previous data in the area, conclusion was drawn that optimal charge may be around 2.0 Kg.

16 holes of common OD were drilled in a small circle (approximately same location). For each setting of fixed pre amplifier gain , three shots of different charge size were taken. A dummy test was taken to have an idea of the cultural noise prevalent in that area.

Data acquired was then analysed.

Analysis of the data

Observations: Comparative study of all the twelve records taken with various Fixed K gain was done based on the below mentioned criteria to arrive at optimal charge size as is done usually by any field observer.

1. Penetration of input signal i.e. observing deeper events as per the objective
2. Overall noise suppression & presence of ground roll
3. Continuity of the event
4. Frequency content in the data
5. Over scaling /amplitude clippings if any

Conclusion was drawn that 2.0 Kg charge was optimal in satisfying above mentioned criteria's at Sl.No 1 to Sl.No 4

Trace data of all files from traces nearest to shot point were collected from the utility software provided by M/s ION and populated on a excel sheet for relevant comparison.

With gain of G0 amplitude clipping of trace data was not observed with a charge magnitude of 1.5 Kg, 2.0 Kg and 2.5 Kg.

With Gain of G2 amplitude clipping of trace data was observed with a charge magnitude of 1.5 Kg, 2.0 Kg and 2.5 Kg from a time of 68 ms (Time break) to 182 ms in only two traces near to shot point.

With gain of G4 moderate amplitude clipping of trace data was observed with a charge magnitude of 1.5 Kg and 2.5 Kg from a time of 68 ms to 506 ms in more than a few traces near to shot point.

With Gain of G6 severe clipping of data was observed with a charge magnitude of 1.5 Kg, 2.0 Kg and 2.5 Kg from a time of 68 ms to 696 ms. as illustrated in Table 2 (highlighted portion shows amplitude clipping).

From the above it is concluded that trace amplitudes decrease exponentially in temporal and spatial domain as we away from source. Also amplitude clipping of traces increases as we move from G0 to G6 gain settings. i. e. more and more traces in the vicinity of the shot point will get clipped. Only solution is to use radial K gain settings for different trace ranges.

Based on the data captured and analyzed in the above field records, radial pre amplifier gain was used and shots were taken with different radius values for different Gain settings.

Trace data with radial Pre amp gain for a radius of 80 m with G0, 80 m to 160 m with Gain G2, 160m to 320 m with Gain G4 and beyond 320 m with Gain G6 was seen as the best radial Gain combination for the location. This data had no clipping of trace amplitudes at any level.

Generally the charge size is reduced due to obstacles and for shallow/less depth shots. But for pattern holes the total charge size may increase which will increase the amplitudes of direct arrivals. Keeping this in mind radial Gain distances ranges were increased and further experiments were conducted.

Amplitude clippings were not observed in any of the traces. In general with the increase in charge size it may be necessary to change the radial distances of different Gain values to accommodate the higher input signals depending upon the location.

Conclusion

It is recommended to use radial pre amplifier gain to avoid the clippings in near traces and to accommodate maximum signal input. The required K gain setting should be decided considering the overall noise prevalent in the area which ultimately sets lower limit of the input signal to the Scorpion[R] system.

Normally there is a feeling that when pre amp gain is increased, some effect in the data should be immediately visible. This does not happen in the Scorpion[R] seismic data acquisition system as gain is removed before recording the data on media. There will also be no significant change in frequency content. Significant change can only be seen from the final processed output after removal of noise. The only results that will be evident with gain change are raw amplitude values of trace data, provided the cultural noise does not mask the data. As we move from G0 to G6 the amplitude addition to trace data will be below 0.000310462589257994 volts to 0.000004850977957156 volts which normally one can find only at the deeper levels if unmasked by the prevalent noise level.

Figure 4 and figure 5 shown below are the frequency spectrum plots of 20 receivers of the farthest line of 80 receivers from shot point with Gain G0 and Gain G6. The receiver line interval was 160 meters and receiver interval was 40 meters. So the receivers of the line whose spectrum plot is displayed below, were at a distance of 1280 meters to 1510 meters from shot point (Asymmetrical spread). As seen in the frequency spectrum plots, when Gain G6 is used, the amplitudes outlined in bands of 10 db levels below 0 dB (normalized) show improvement over the data with Gain

G0 in the entire frequency band. The situation is similar when Gain G2 and Gain G4 are applied. The best combination will be to use Radial Pre amplifier Gain combination so that there are no amplitude clippings from near traces and amplitudes at farthest traces are maximized.
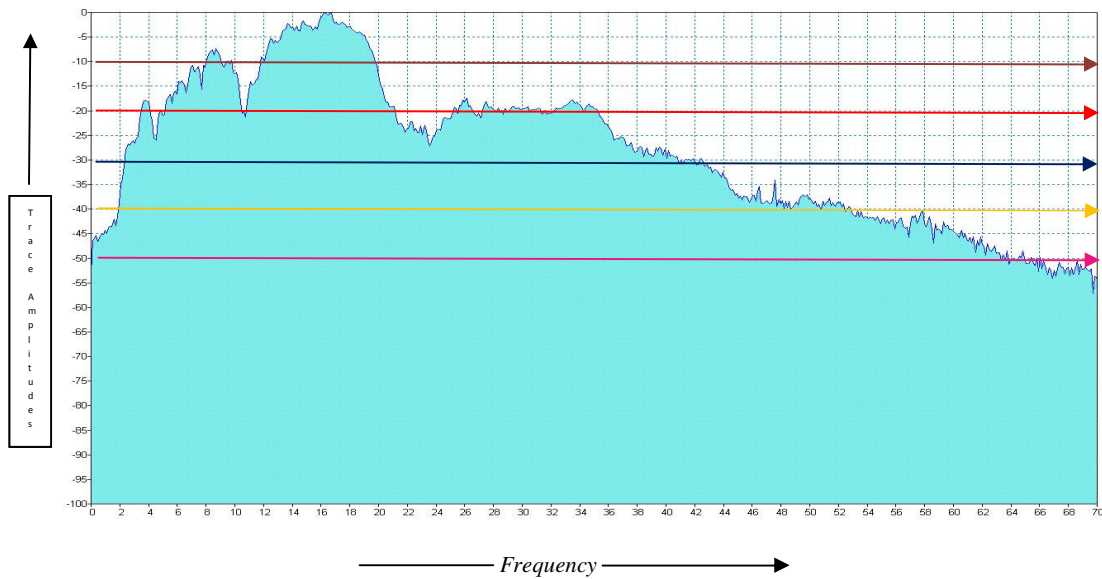

Fig 4: Frequency spectrum of farthest receiver line (20 traces) from Shot point: Gain G0 Charge Size: 2.5 Kg
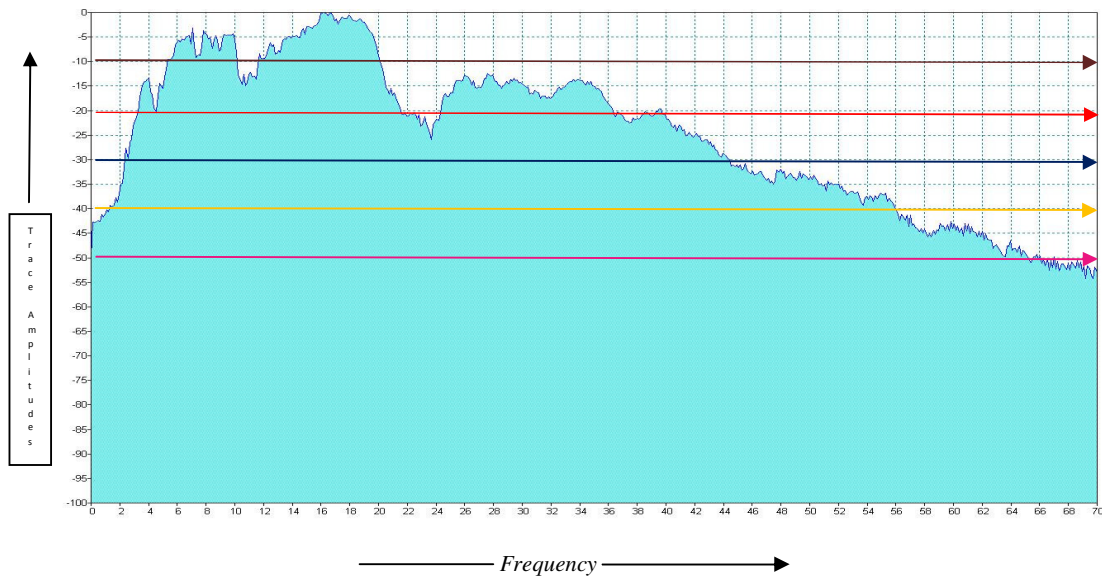

Fig 5: Frequency spectrum of farthest receiver line (20 traces) from Shot point: Gain G6 Charge Size: 2.5 Kg

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As already mentioned, the apparent change will be in the amplitudes across the frequency spectrum. The possibility of the removal of cultural noise prevalent in the field will be the important factor in having an improved seismic data set when using the G6 gain.

As pre amplifier gain increases from G0 to G6 the instantaneous dynamic range of the system decreases from 130 dB to 110 dB. It should be noted that the recording system has much more dynamic range than other elements in the seismic system. For example, a typical Fast Fourier Transform used in processing has only about 80 dB of dynamic range due to mathematical noise (due to accumulated round-off error over many multiplications and additions). More sophisticated numerical methods may provide up to about 100 dB of clarity. However the noise floor in seismic records is often the most limiting factor. Therefore, whether the instrument provides a net 110 dB or 130 dB is generally irrelevant. Ability to access data is limited by the most restrictive dynamic range limitation in the seismic system. The seismic system includes everything from parameter design, through source and receiver coupling, the recording system, the tape format, the implementation of FFTs in processing and even the display of data during interpretation. As Scorpion[R] systems instantaneous dynamic range (even at 110 dB with G6 gain) exceeds many other limits normally encountered, there is no need to worry about the theoretical loss of 20 dB when using higher gain.

				TRACE AMPLITUDES (Shot point 210.5 Gain G6 Charge Size: 2.5 Kg)		
Time ms	Trace 208	Trace 209	Trace 210	Trace 211	Trace 212	Trace 213
68	-0.013636098243000000	0.015484320931000000	-40.692951202393000000	-4.953833103180000000	0.010701256804000000	-0.025666523725000000
70	-0.016638854519000000	-0.003972950857000000	-40.692951202393000000	-21.593206405640000000	0.006941749249000000	-0.025123214349000000
72	-0.019675565884000000	-0.411241650581000000	-40.427490234375000000	-40.692951202393000000	0.003555766772000000	-0.027204284444000000
74	-0.019447570667000000	-3.993688821793000000	-6.650307178497000000	-40.692951202393000000	-0.000945940672000000	-0.024681774899000000
76	-0.018482225016000000	-18.355741500854000000	40.692947387695000000	-36.009006500244000000	-0.009221708402000000	-0.016954166815000000
78	-0.019180765375000000	-40.692951202393000000	40.692947387695000000	4.233079433441000000	-0.097839370370000000	-0.012132295407000000
244	40.692947387695000000	-40.692951202393000000	-40.692951202393000000	-40.692951202393000000	40.692947387695000000	40.692947387695000000
246	40.692947387695000000	-40.692951202393000000	-40.692951202393000000	-40.692951202393000000	40.692947387695000000	40.692947387695000000
248	40.692947387695000000	-40.692951202393000000	-40.692951202393000000	-40.692951202393000000	40.692947387695000000	40.692947387695000000
250	40.692947387695000000	-40.692951202393000000	-40.692951202393000000	-40.692951202393000000	40.692947387695000000	40.692947387695000000
316	40.692947387695000000	40.692947387695000000	-40.692951202393000000	-40.692951202393000000	40.692947387695000000	-40.692951202393000000
318	40.692947387695000000	40.692947387695000000	-40.692951202393000000	-40.692951202393000000	40.692947387695000000	-40.692951202393000000
320	40.692947387695000000	40.692947387695000000	-40.692951202393000000	-40.692951202393000000	40.692947387695000000	-40.692951202393000000
322	40.692947387695000000	39.632751464844000000	-40.692951202393000000	-40.692951202393000000	40.692947387695000000	-40.692951202393000000
512	40.692947387695000000	-40.692951202393000000	-33.929344177246000000	40.692947387695000000	40.692947387695000000	-13.146741867065000000
514	40.692947387695000000	-40.692951202393000000	-40.692951202393000000	40.692947387695000000	40.692947387695000000	-1.791689276695000000
896	-0.271630495787000000	8.365758895874000000	11.142371177673000000	1.228781819344000000	17.278032302856000000	-40.692951202393000000
898	0.542669177055000000	7.728650569916000000	10.947953224182000000	0.082524836063000000	15.613318443298000000	-40.692951202393000000

Table 2: Clipping of raw amplitude values of traces nearest to shot point with Gain of G6

Reservation with using radial Gain: It has been seen that in crews which do not use integrated GPS with Shotpro[R] (Blaster unit of Scorpion[R]) recovery shots are taken regularly but the shot point co ordinates for the recovery data are received very late by the observers. This poses a problem for them to incorporate the exact co-ordinates in the Input SPS file. Also the Radius decided earlier for application of pre amplifier gain may be different for the recovery shots. In Scorpion[R] system the method to circumvent this problem would be to take all recovery shots by associating them with a different acquisition process flow in which a different radial gain can be used.

Applications:

1. Looking below trap where there is low illumination due to less signal transmission.
2. For mapping deep basin centered gas exploration.
3 In general, higher pre-amp gains are used in areas of known weak input signal and when using lower energy sources such as Vibroseis, air gun and weight drop. In cases where small receiver intervals bring several receiver groups close to the source point (smaller bin size), there may be overdriving of near-offset channels. If offsets distances are long, then maximum pre-amplifier gains should be selected to ensure that the full dynamic range of the Delta-Sigma A-D converter is utilized. Radial Pre amplifier gain is best suited for this purpose as in normal oil and gas exploration programs getting good energy at far offsets is very important.

Methodology for charge optimization and gain setting

1. Identify the experimental location in the working area.
2. Carry out an experimental up hole and fix the OD. Drill required number of shot holes with the same OD in small area around the picket.
3. Ascertain the tentative range of the charges to be used from previous data set. Say 1.5 Kg to 2.5 Kg

4. Start with G-6 gain and take records of above charges.
5. Study these records with respect to charge optimization parameters and trace amplitude clippings. Start from lowest charge denomination. If there is amplitude clipping go to the next gain G-4 setting (One step below).
6. Carry out similar experimentation with G-4 gain settings.
7. Repeat the process given at point No.5. If there is trace amplitude clipping go to the next gain G-2 setting.
8. Carry out similar experimentation with G-2 gain settings.
9. Repeat the process given at point No.5. If there is trace amplitude clipping go to the next gain G-0 setting. This process ultimately evolves to optimal charge with corresponding fixed gain settings. It is observed that single gain setting does not suffice for entire offset ranges. Hence it is preferred to use RADIAL gain setting in place of fixed gain setting.

To arrive at different offset ranges with corresponding gain settings follow the procedure as given below.

Methodologies for radial K gain setting.

Analyze the trace data from all traces nearest to the shot point by exporting the trace data on to an Excel spread sheet. Check for trace amplitude clippings at various time intervals. Based on the clipping of trace data, values of the different radius for application of Pre amplifier gain may be firmed up.

This will ultimately provide the data without any trace amplitude clipping and with perfect charge optimization.

References

Literature provided by M/s ION Geophysical Corporation

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