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Radial Gain and its Advantages in Seismic Data Acquisition

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Summary

This paper explains the theory behind the radial gain and fixing of the parameters for applying radial gain while acquiring the seismic data to improve the frequency bandwidth and continuity of events at deeper events.

Introduction

Evaluation of electronics has started from vacuum tube to transistor to (IC) chips. In 1948 Bell Labs invented a semiconductor device called a transistor, which performed the same functions as the vacuum tube, but it had the advantage of being much smaller in size and was more efficient, operated cooler, faster, and at much lower power levels. They were considerably more rugged than tubes, able to sustain high impact loads. Because of the transistor, vacuum tubes died hard and finally became obsolete. Needless to say, electronics is the silent servant that touches every aspect of day-to-day life, without it, the modern world would grind to a halt. The advent of modern electronics came into being at just the right time, because the Space Age would never have blossomed forth without miniature transistorized circuits and the later more compact Integrated Circuits (IC). Satellite design constraints of weight and size have necessitated even more compact electronic chips. Space systems and modern electronics go hand in hand as they promote each other. Electronics complements modern life, and is master over every technical and scientific and commercial endeavor.

In phase with the evaluation of electronics the seismic data recording systems and their field electronics were also evolved using vacuum tubes, transistors and chips. The first phase of seismic data acquisition systems and their ground electronics had used vacuum tubes which are susceptible to failures under the conditions of rough handling which is usually present when the equipment is used in the field and big in size & was not field portable. The above problems were overcome by utilizing the technology of solid-state devices (transistors), but they do have certain disadvantages like more circuit noise. As the technology advanced to chips and workstation, recording and its ground equipment had become miniature and field portable and reduced noise and increased dynamic range.

There is a growing concern in the industry about the quality of seismic data acquired by Seismic Data Acquisition Systems today. For many years the tests have been run on acquisition hardware to ensure that they are within the specifications of manufacturers before the data recording. These tests are well established and with computer analysis provide unambiguous numerical values for system noise, distortion, dynamic range, pre-amp gain etc which can be compared with manufacturers published specifications.

In-order to properly record the seismic signals; it is necessary to provide an amplifier system that amplifies signals before recording. The amplitude of the seismic signals is more at near offset channels and decreases rapidly thereafter. It is also desirable to fine tune the characteristics of amplifying system in response to the weaker signals.

The pre-amp gain plays a major role in boosting and bringing the weaker signals to the level of A/D converter from far offsets and deeper targets. The Pre-amp gains of Texas Instruments were 0,12,24,36 and 48 db with 16 bit A/D conversion and 80 db dynamic range. Similarly Sercel systems have 0, 12 and 24 db gains with 24-bit A/D conversion and 138 db dynamic range. The latest ION equipment also has 0, 12, 24 and 36 db gain with 24-bit A/D conversion and 138 db Dynamic range. Different systems will record minimum possible values depending on their pre-amp gains. The minimum and maximum possible amplitude values that can be recorded with ION system are

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0.000004mv (min) and 2500mv (max) (figure.1) depending on the pre-amp gains. The pre-amp gain factor is stored in trace header byte.

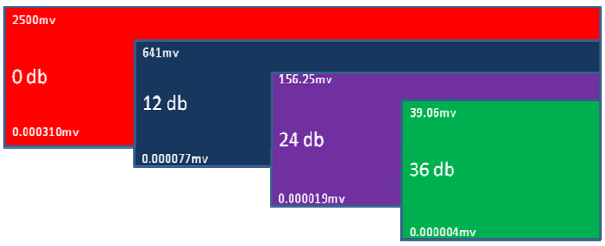


Figure.1

Above diagram shows, when 0 db pre-amp gain is applied the system is able to record 2500 mill volts maximum signal amplitude and 0.310 micro volts minimum values which is the restriction of A/D converter. When 12 db pre-amp gain is applied the system is able to record 641mv and 0.077microvolts. Here the signals have started clipping above 641mv but lower limit has increased fourfold. Similarly with 36 db pre-amp gain signals above 39.06mv will clip but lower limit has increased to 32 fold which is 4 nano volts. Due to this definition associated with fixed pre-amp gain, data will be losing either higher amplitude values or lower amplitude values.

It is necessary to have facility to record all the four pre-amp gains so that no information is lost by which higher amplitudes at near offsets as well as lower amplitudes at far & deeper targets are recorded faithfully. This can be achieved by **RADIAL GAIN,** the facility available with latest recording systems.

Radial gain applies variable pre-amp gain with varying radius from the shot point. This will preserve the higher and lower energies sensed by the geophone. This will enable us to record all the signals faithfully to map the subsurface more accurately and will enable geophysicist to analyse the seismic attributes in a meaningful way which may lead to deciphering the sub surface for hydrocarbon discovery. The System boost the geophone signals with given gain factor, digitizes them and sends them to recording system, before it is written to the SEG-Y tape. The gain applied is removed from each sample so that the true input signals are written to the tape. No reverse gain needs to be applied at processing centre. This data can be treated as true input data and normal processing sequences can be carried out.

Methodology to calculate radial distance:

Radius for G0 (Distance in Meters)

The Analog Unit amplifier gain will be defined as G0 for the distance from the shot point to the receiver at which the amplitude starts diminishing from a critical value (0.000314 mv) The system uses this number as the radius of a circle centered on the shot point. Any Analog Unit receiver on any line within this radius will have is gain set to G0 (0 db).

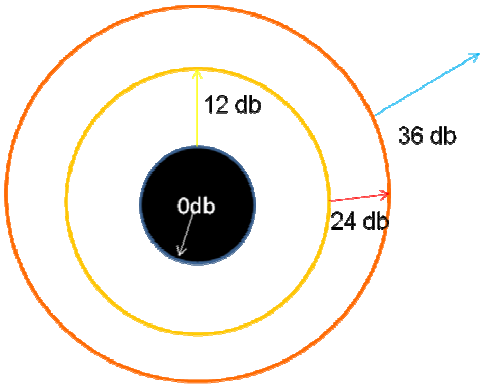
Radius for G2 (Distance in Meters)

The system uses this number as the radius of a circle centered on the shot point. Any receiver on any line between this radius and the preceding radius parameter will have it's gain at G2 (12 db).

Radius for G4 (Distance in Meters)

The system uses this number as the radius of a circle centered on the shot point. Any receiver on any line between this radius and the preceding radius parameter will have it's gain at G4 (24 db).

Note: All remaining receiver outside the last configured radius will have it's gain at G6 (36 db). If the final gains for all receivers outside the radius are intended to be a lower gain, adjust the radius distance value for the desired maximum gain setting to include the entire active spread.



The Figure: 2 represent the radial gain radius

The Dynamic Range of the system with 24 bit A/D conversion for each pre-amp gain is shown in table.1 and the dynamic range is 138 db which is almost equal as dynamic range of geophone (140 db).

Table: 1

mv (max)	mv (min)	Dynamic Range	Pre Amp Gain
2500	0.0003104600	-138	0db
625	0.0000776150	-138	12db
156	0.0000194039	-138	24db
39.1	0.0000048509	-138	36db

Four records with different pre-amp gain were analyzed for a particular trace (figure.3) which has given us a clue to go for a radial gain adaption. If we look at amplitude levels of trace in the fallowing four records, the system has recorded the minimum possible values with given pre-amp gain. If we had gone with 0/12/24 db gain we would have lost the energy that was being sensed by geophone (0.000004 microvolt) due to A/D converter restriction. With adaption of radial gain it is possible to record the maximum and minimum possible values without clipping. With increase in pre-amp gain the signal and noise level as well will increase, however the noise can be filtered out with the advent of effective filtering modules available in processing software. However there is no mechanism to retrieve the data which is not recorded. Therefore it is desirable to record as much information as possible with in the dynamic range of the system and effectively filtering the noise at processing stage. The aim of radial gain is to record maximum (2500mv) and minimum (0.000004microvolt) values without clipping.

The effect of fixed gain on the data is shown bellow in figure 3,4,5 and 6.

Effect of Fixed Gain (G0) (0 Db)

46.00	0x39A2C595	0.000310462579
48.00	0x39A2C595	0.000310462579
50.00	0x39A2C595	0.000310462579
52.00	0x39A2C595	0.000310462579
54.00	0x39A2C595	0.000310462579
56.00	0x39A2C595	0.000310462579
58.00	0x39A2C595	0.000310462579
60.00	0x39A2C595	0.000310462579
62.00	0x39A2C595	0.000310462579
64.00	0x39A2C595	0.000310462579
66.00	0x39A2C595	0.000310462579
68.00	0x39A2C595	0.000310462579

Figure.3 shows minimum value 0.000314 mv for G0 gain

Effect of Fixed Gain (G2) (12 Db)

46.00	0x38A2C595	0.000077615645
48.00	0x38A2C595	0.000077615645
50.00	0x38A2C595	0.000077615645
52.00	0x38A2C595	0.000077615645
54.00	0x38A2C595	0.000077615645
56.00	0x38A2C595	0.000077615645
58.00	0x38A2C595	0.000077615645
60.00	0x38A2C595	0.000077615645
62.00	0x38A2C595	0.000077615645
64.00	0x38A2C595	0.000077615645
66.00	0x38A2C595	0.000077615645
68.00	0x38A2C595	0.000077615645

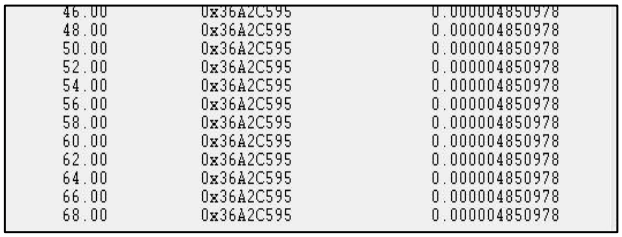
Figure.4 shows minimum value 0.0000776 mv for G2 gain

Effect of Fixed Gain (G4) (24 Db)

46.00	0x37A2C595	0.000019403911
48.00	0x37A2C595	0.000019403911
50.00	0x37A2C595	0.000019403911
52.00	0x37A2C595	0.000019403911
54.00	0x37A2C595	0.000019403911
56.00	0x37A2C595	0.000019403911
58.00	0x37A2C595	0.000019403911
60.00	0x37A2C595	0.000019403911
62.00	0x37A2C595	0.000019403911
64.00	0x37A2C595	0.000019403911
66.00	0x37A2C595	0.000019403911
68.00	0x37A2C595	0.000019403911

Figure.5 shows the min value 0.0000191 mv for G4 gain

Effect of Fixed Gain(G6) (36 Db)



46.00	0x36A2C595	0.000004850978
48.00	0x36A2C595	0.000004850978
50.00	0x36A2C595	0.000004850978
52.00	0x36A2C595	0.000004850978
54.00	0x36A2C595	0.000004850978
56.00	0x36A2C595	0.000004850978
58.00	0x36A2C595	0.000004850978
60.00	0x36A2C595	0.000004850978
62.00	0x36A2C595	0.000004850978
64.00	0x36A2C595	0.000004850978
66.00	0x36A2C595	0.000004850978
68.00	0x36A2C595	0.000004850978

Figure.6 shows the min value 0.0000191 mv for G6 gain

Parameter fixation for radial gain through experimentation

To fix the parameters the following are the pre requisites:

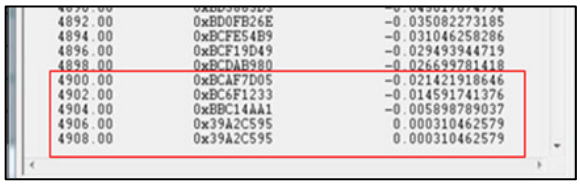
Optimizing the Charge and Depth– To finalize the proper charge and depth

Preparation of SPS with pre stacked co-ordinates and loading in the system—this facilitates in applying appropriate gain to the proper receiver and to do On-Line QC of shots and receivers.

After Charge and Depth have been optimized, four shots have been taken with 0, 12, 24 and 36 db gains which is pre-amp gain (PAG) test.

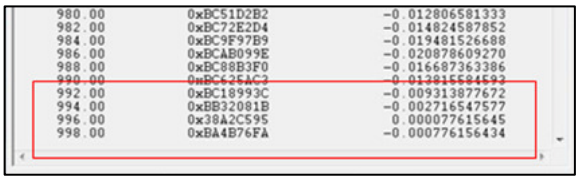
HOW TO CALICULATE RADIAL DISTANCE:

From the numerical display as in figure.6. The minimum amplitude level (0.000310mv) and corresponding trace number is to be noted by which the maximum distance up to which 0db gain is applied. Similarly as in figure. 7 and 8 the maximum distance up to which 12 and 24 db gains are applied



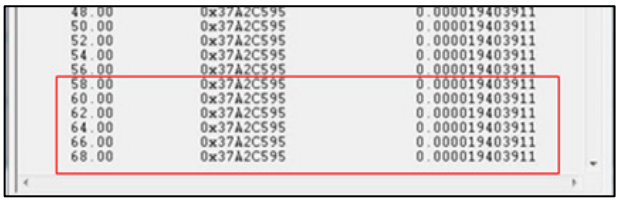
4892.00	0xBD0FB26E	-0.035082273185
4894.00	0xBCFE54B9	-0.031046258286
4896.00	0xBCF19D49	-0.029493944719
4898.00	0xBCDAB980	-0.026699781418
4900.00	0xBCAF7D05	-0.021421918646
4902.00	0xBC6F1233	-0.014591741376
4904.00	0xBBC14AA1	-0.005898789037
4906.00	0x39A2C595	0.000310462579
4908.00	0x39A2C595	0.000310462579

Figure.6 shows min amp. value away from shot point



980.00	0xBC51D2B2	-0.012806581333
982.00	0xBC72E2D4	-0.014824587852
984.00	0xBC9F97B9	-0.019481526688
986.00	0xBCAB099E	-0.020878609270
988.00	0xBC88B3F0	-0.016687363386
990.00	0xBC625AC3	-0.013815584693
992.00	0xBC18993C	-0.009313877672
994.00	0xBB32081B	-0.002716547577
996.00	0x38A2C595	0.000077615645
998.00	0xBA4B76FA	-0.000776156434

Figure.7 shows min amp. value away from shot point



48.00	0x37A2C595	0.000019403911
50.00	0x37A2C595	0.000019403911
52.00	0x37A2C595	0.000019403911
54.00	0x37A2C595	0.000019403911
56.00	0x37A2C595	0.000019403911
58.00	0x37A2C595	0.000019403911
60.00	0x37A2C595	0.000019403911
62.00	0x37A2C595	0.000019403911
64.00	0x37A2C595	0.000019403911
66.00	0x37A2C595	0.000019403911
68.00	0x37A2C595	0.000019403911

Figure.8 shows min amp. value away from shot point

The channels falling beyond this radius will be automatically applied 36 db gain by the system. The obtained distance with respect to corresponding gains are fed in to the system and regular seismic data acquisition was carried out. It is to be noted that the pre-amp gains, which are applied on data, are removed before it is written to the tape. The gain applied to each trace is stored in SEG-Y trace header.

COMPARATIVE STUDY

(SPECTRAL ANALYSIS & BRUTE STACK SECTIONS)

An experiment was done to compare the efficacy of fixed and radial gain.

An experiment was conducted with regular spread of 10 lines with 25 shots of each fixed gain and radial gain. All the receiver lines for all the shots taken with fixed and radial gain were subjected to frequency analysis to obtain the frequency spectrum for each shot point and receiver line. Total of 500 receiver lines were analyzed. Fig.9 shows the layout of receiver lines and shot configuration. The shot for fixed gain and radial gain were fixed adjacent to each other.

Layout of Experimental Shots

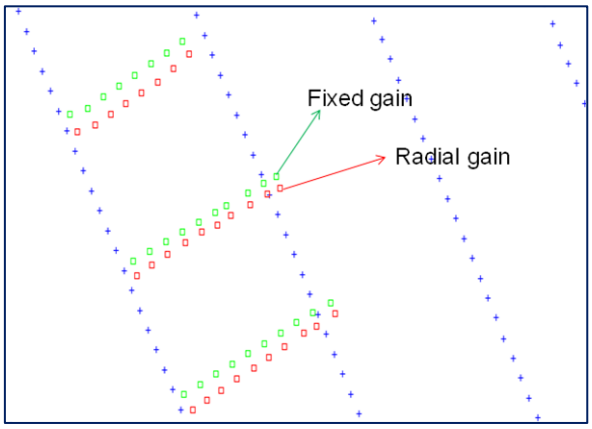


Figure.9 shows the shots and receiver layout of experiment

Spectral Analysis

The fallowing figure.10 shows the spectral analysis and its comparison between fixed gain and Radial gain.

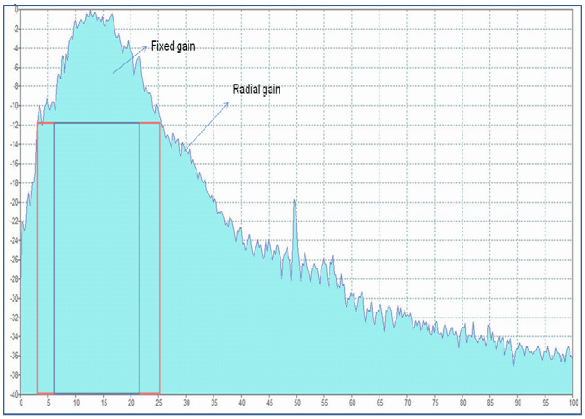


Figure.10 shows spectral comparison

Figure10 shows the frequency spectrum for one such shot location. The frequency band at lower end as well as higher end is expanded for radial gain when compared to fixed gain. The band width increase is consistent for all 25 shots and for all lines (figure.11).

Bandwidth plot of all ten lines for one record (fixed and radial gain) as in figure.11

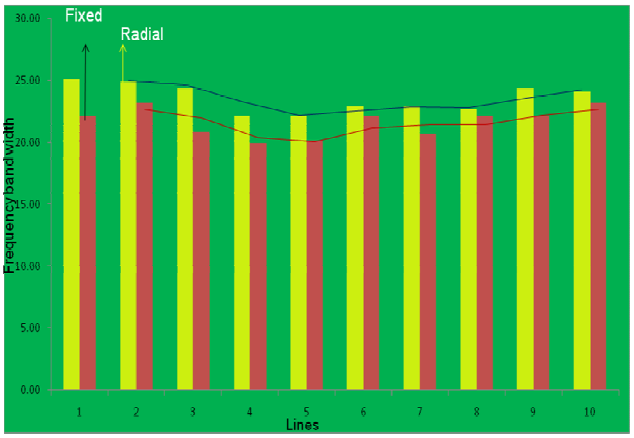


Figure.11 shows bandwidth comparison of fixed and radial gain shots

Spectral Analysis of Experimental Data

The following table.2 shows the frequency spectrum of all 50 shots (fixed and radial gain) for 4 receiver lines. The analysis shows an increase frequency on low side and high side of the frequency spectrum.

Table.2

Line	191		209		227		245.0	
Frequency(Hz)	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
3567 (Radial)	5.1	25.1	3.4	24.9	1.9	24.4	2.2	22.2
3573 (Fixed)	6.3	22.2	5.6	23.2	2.4	20.9	2.2	20
Difference	**-1.2**	**2.9**	**-2.2**	**1.7**	**-0.5**	**3.5**	**0.0**	**2.2**
3556 (Radial)	6.1	24.4	5.4	27.3	1.9	25.3	2.2	24.4
3557 (Fixed)	6.3	22.9	5.6	22.9	2.4	21.4	2.2	22.7
Difference	**-0.2**	**1.5**	**-0.2**	**4.4**	**-0.5**	**3.9**	**0.0**	**1.7**
3555 (Radial)	6.5	18.5	5.8	19.7	2.7	18.8	2.2	20
3554 (Fixed)	6.3	17.3	5.6	19.5	2.7	18.5	1.9	19.8
Difference	**0.2**	**1.2**	**0.2**	**0.2**	**0**	**0.3**	**0.3**	**0.2**
3553 (Radial)	6.3	23.4	5.8	26.8	2.2	27.1	2.2	24.4
3552 (Fixed)	6.3	19	5.8	20	2.2	19.5	2.2	20
Difference	**0**	**4.4**	**0**	**6.8**	**0**	**7.6**	**0.0**	**4.4**
3550 (Radial)	6.1	28.5	5.4	27.6	2.2	27.1	1.9	26.6
3551 (Fixed)	6.3	22.2	5.8	24.4	2.9	22.2	2.2	22.7
Difference	**-0.2**	**6.3**	**-0.4**	**3.2**	**-0.7**	**4.9**	**-0.30**	**3.9**
3508 (Radial)	5.85	26.8	3.17	27.3	2.2	25.6	1.7	27.1
3518 (Fixed)	5.37	23.2	5.37	24.9	5.1	23.4	1.9	23.9
Difference	**0.48**	**3.6**	**-2.2**	**2.4**	**-2.9**	**2.2**	**-0.2**	**3.2**
3509 (Radial)	3.4	24.2	3.2	26	2.4	25	2.2	25
3519 (Fixed)	4.6	24.2	5.8	25	2.2	26	1.9	25
Difference	**-1.2**	**0.03**	**-2.6**	**0.7**	**0.2**	**-0.3**	**0.3**	**0.1**
3513 (Radial)	2.9	25.6	2.6	27	1.4	25	1.9	25
3520 (Fixed)	6.3	21.4	5.8	24	1.9	25	2.1	24
Difference	**-3.4**	**4.2**	**-3.2**	**2.9**	**-1**	**-0.2**	**-0.2**	**1.1**
3514 (Radial)	2.9	22.2	2.9	27	1.9	26	1.7	25
3521 (Fixed)	6.34	21.9	3.1	24	1.9	25	1.7	23
Difference	**-3.4**	**0.3**	**-0.2**	**2.7**	**0**	**1**	**0**	**1.7**
3515 (Radial)	3.9	22.9	2.9	25	2.2	24	2.2	22
3522 (Fixed)	4.6	22.7	3.2	23	2	23	2.2	23
Difference	**-0.7**	**0.2**	**-0.3**	**1.8**	**0.2**	**0.8**	**0**	**-0.5**
3516 (Radial)	3.9	23.4	2.9	25	1.9	25	2.2	23
3523 (Fixed)	3.6	23.1	2.7	23	1.9	23	2.2	22
Difference	**0.3**	**0.3**	**0.2**	**1.5**	**0**	**1.5**	**0**	**0.7**
3568 (Radial)	5.6	22.4	3.4	23	1.9	22	2.4	20
3572 (Fixed)	6.1	21.9	3.6	23	1.9	22	2.2	22
Difference	**-0.5**	**0.5**	**-0.2**	**0.3**	**0**	**-0.1**	**0.2**	**-2.2**
3647 (Radial)	**4.6**	**20**	**2.7**	**23**	**1.9**	**17.3**	**2.2**	**16.6**
3636 (Fixed)	**6.3**	**17**	**3.4**	**24.1**	**2.2**	**19.2**	**2.2**	**19**
Difference	**-1.7**	**3**	**-0.7**	**-1.1**	**-0.3**	**-2**	**0**	**-2.4**

Compression of monitor records:

Improved Continuity of Events with Radial Gain (5kg, 30.7m) as in figure.12

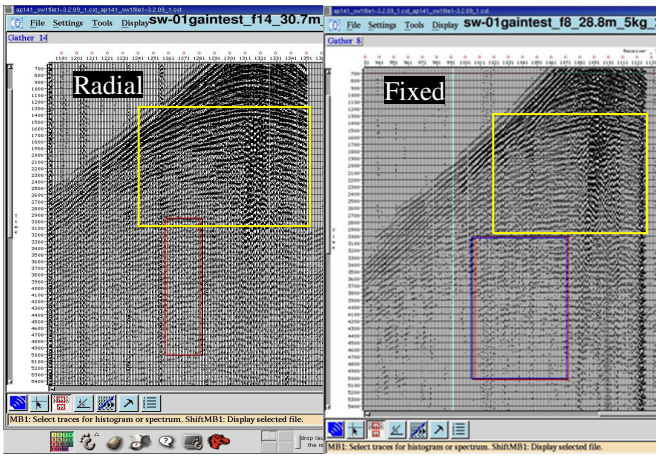


Figure.12 shows monitor records comparison of radial and fixed gain shots.

Similarly in a shot gather (Figure.12) a comparison is made for both the gains. In the monitor record corresponding to radial gain the events at shallow level as at deeper level are prominent in the demarcated frames.

Analysis Results and Conclusion

It is observed that there is over all increase in band width at lower side as well as at higher side which will help in bringing reflection events more prominently. A seismic section obtained by using radial gain is shown in Figure.13 and 14. In the figures, it is observed that the deeper events are more predominant than the sections from previous vintage. It is concluded that Radial gain is of immense help when a geophysicist is looking for minor changes in geological formations which may be lacales for smaller oil pools.

PSTM stack section of sw6 acquired with radial gain applied shown in figure.13 where the events are prominently seen at 5 seconds.

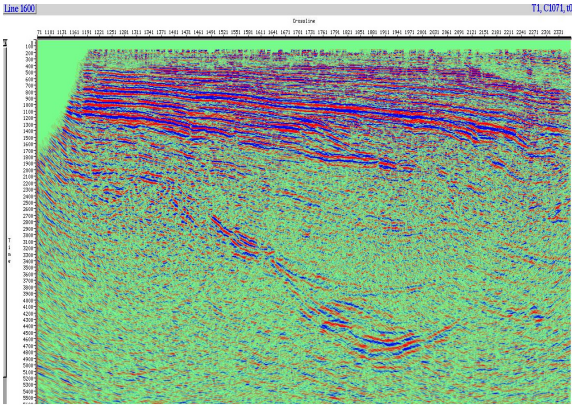


Figure.13 shows the final PSTM Section of swath 6

PSTM stack section of sw8 acquired with radial gain applied is shown below in figure.14. where the events are clearly seen even below 5 seconds. For the first time the basement is cleanly mapped and syn-rift features are observed beyond 5 seconds.

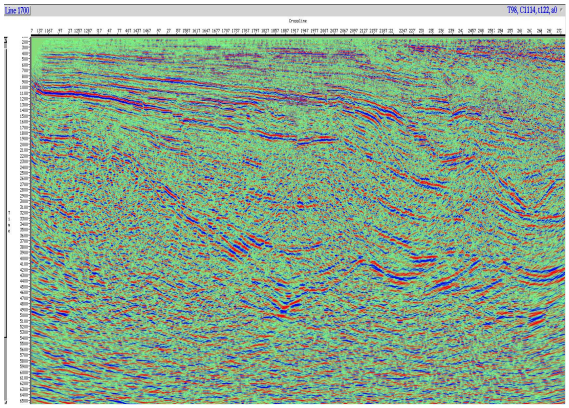


Figure.14 shows the final PSTM Section of swath 8

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