Teknologi Broadband Seismik (Marine Seismic)

Oleh:
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PUSLITBANG GEOLOGI KELAUTAN
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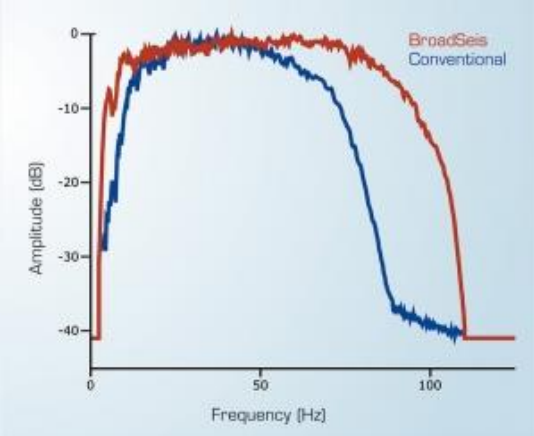
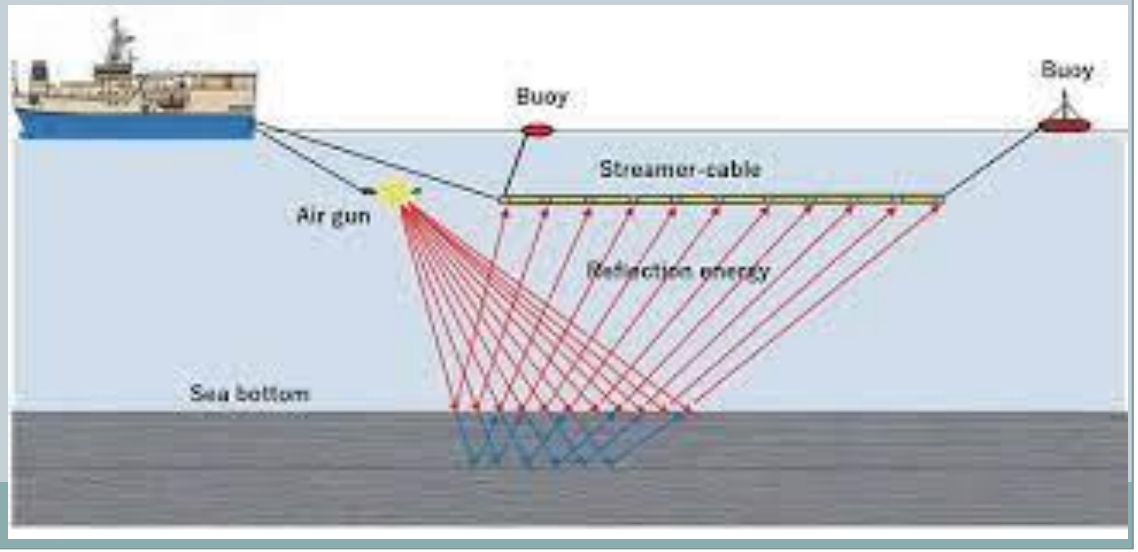
BACKGROUND

In conventional marine seismic acquisition, a ship tows receivers (1 to 12 streamers at depths varying from 7 m to 12 m) and a seismic source (generally an array of airguns at depths between 4 m and 7 m). Several new developments have lead to improved marine imaging.



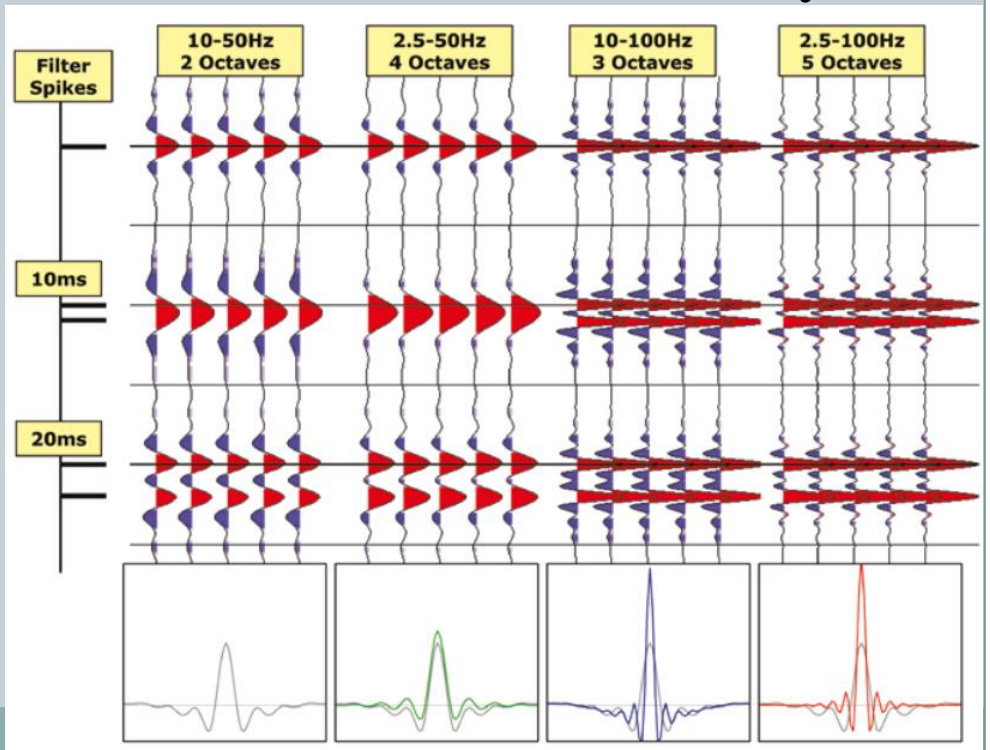
Eric V. Gallant, Robert R. Stewart, Don C. Lawton, Malcolm B. Bertram, and Carlos Rodriguez



BACKGROUND

Broad bandwidth is desirable because it produces sharper wavelets for better resolution of important features such as thin beds and stratigraphic traps. Low frequencies provide better penetration for deep targets, as well as better stability for inversion.

Resolution vs Penetration



Robert Soubaras and Robert Dowle, CGG Veritas

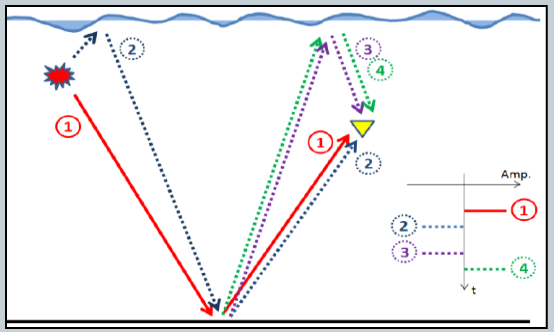
Problematika:
Batasan terhadap Rentang Frekuensi

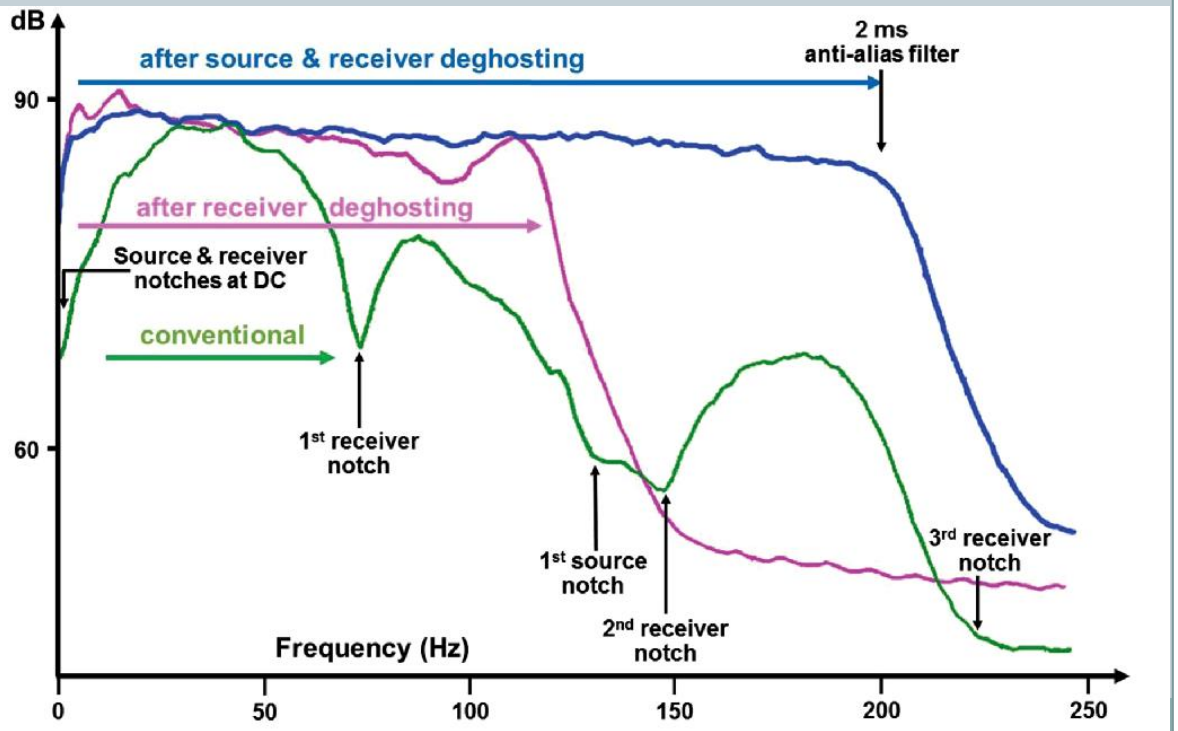
Gangguan noise permukaan air laut, *swell noise*. *Ghost* merupakan refleksi yang diterima receiver setelah dipantulkan oleh batas horison antara udara, air laut dan permukaan dasar laut, ada 3 jenis ghost meliputi *source ghost*, *receiver ghost* dan *source-receiver ghost*.

The sea surface ghost reflections modulate the spectrum of conventional pressure seismic data reducing energy at the so-called notch frequencies

$$f_n = \frac{nc}{2z}, \qquad n = 0, 1, 2, \ldots, \qquad (1)$$

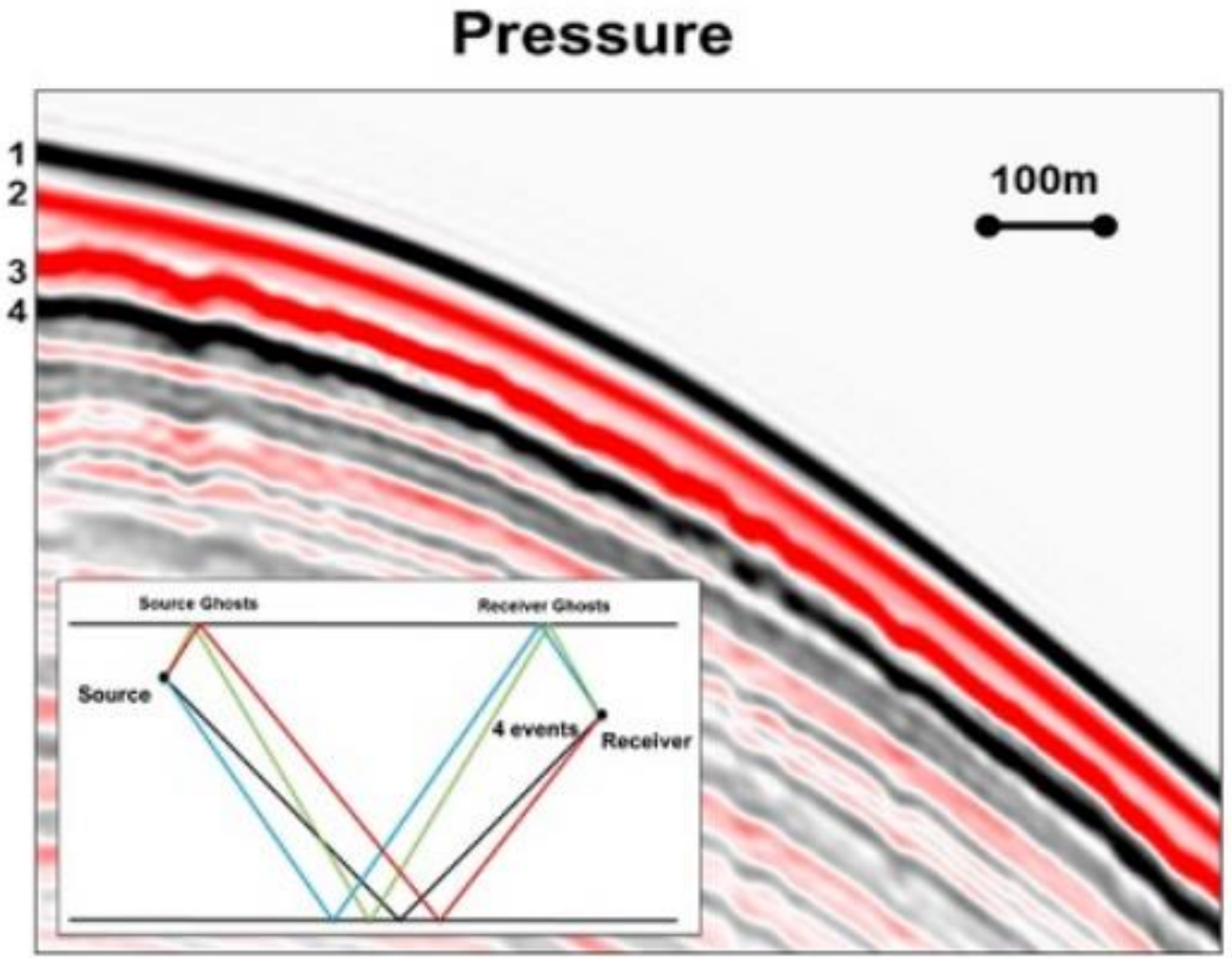
where c is the speed of sound in water and z is the source or receiver depth. The first notch is always at zero frequency. The second and





Amplitude spectra of a seismic image from a conventional marine survey compared with broadband acquisition

Problematika: Fenomena Ghost



Broadband Marine Seismic

- Broadband seismik merupakan data seismik yang memiliki bandwith frekuensi yang lebar.
- Seberapa besar bandwith frekuensi seismik dibatasi oleh kandungan frekuensi sumber.
- Bandwithnya lebih lebar dari data seismik konvensional.
- Data broadband seismik telah mengeliminasi dan mereduksi fenomena *ghost* dan *surface noise* yang membatasi kandungan frekuensi.
- Meningkatkan resolusi untuk target dangkal dan penetrasi untuk target dalam.

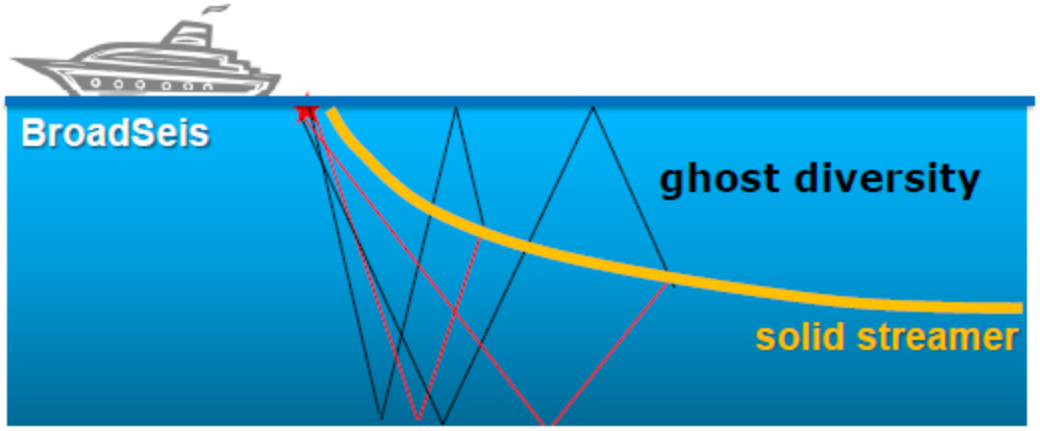
Pengembangan Broadband Marine Seismik

- Data Acquisition
  1. Variable Depth Streamer/Slant streamer
  2. Over-Under Streamer: Western Geco/Shcumberger
  3. Dual Sensor Streamer: PGS
  4. Multilevel Airgun Source
- Data Processing
  1. Broadband Processing for Conventional Marine Seismic
  2. Broad Processing related to acquisition technique

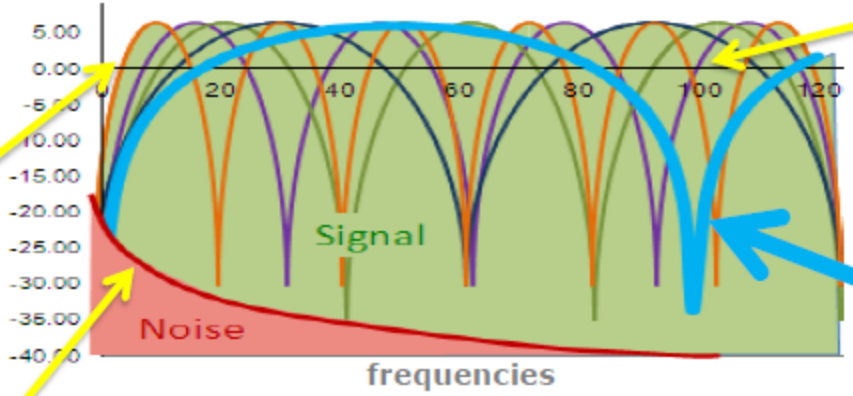
Pengembangan Broadband Marine Seismik

Technique	Towage	Ghost reflection removal	Comments
Multicomponent streamers: GeoStreamer, Nessie-6 (WG), Sentinel MS (Sercel)	Deep tow	Wavefield separation	The most accurate and ingenious method for removing ghost reflections. More often used in ocean bottom acquisition systems
Over-under technique: DISCover (WG)	Towing streamers at shallow depth and deep depth	A number of valleys in amplitude spectrum	There is a set of valleys before and after stacking. Therefore, there should be twice as many streamers
Oblique streamers: Broadseis (CGG), ObliQ (WG)	Oblique tow: from shallow depth to deeper depth	A number of valleys in amplitude spectrum	There is a set of valleys only after stacking. Elimination of ghost arrivals before stacking is based on processing algorithms (below)
Data processing: WiBand (GXT), Clari-Fi (TGS), SHarp (Dolphin), etc.	Shallow depth tow	Amplification of low frequencies	Data processing focuses on a high signal/noise ratio at low frequencies in spite of shallow towing
	Deep tow	Separation of frequencies	Data processing focuses on retrieving signals whose frequencies are in spectral valleys

Variable Depth Streamer Acquisition



Acquired Signal for any frequency bandwidth

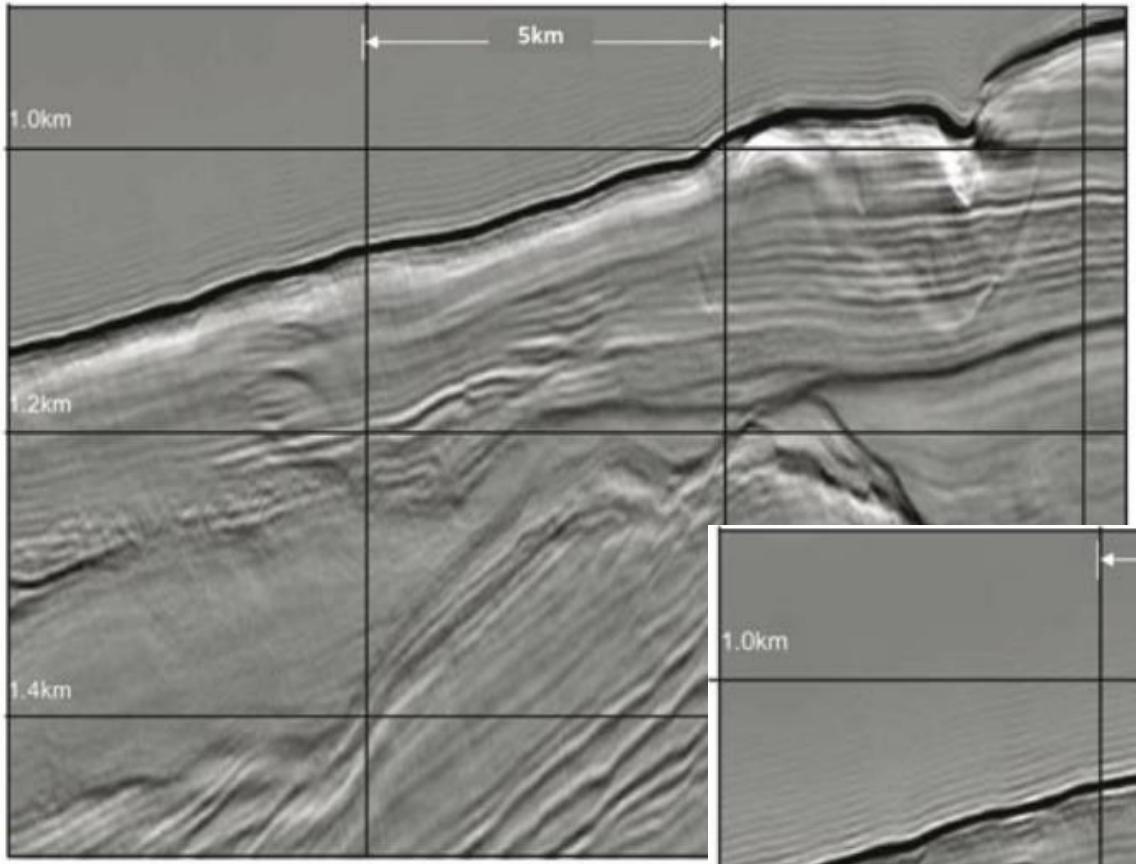


Extra Noise Free Low Frequencies

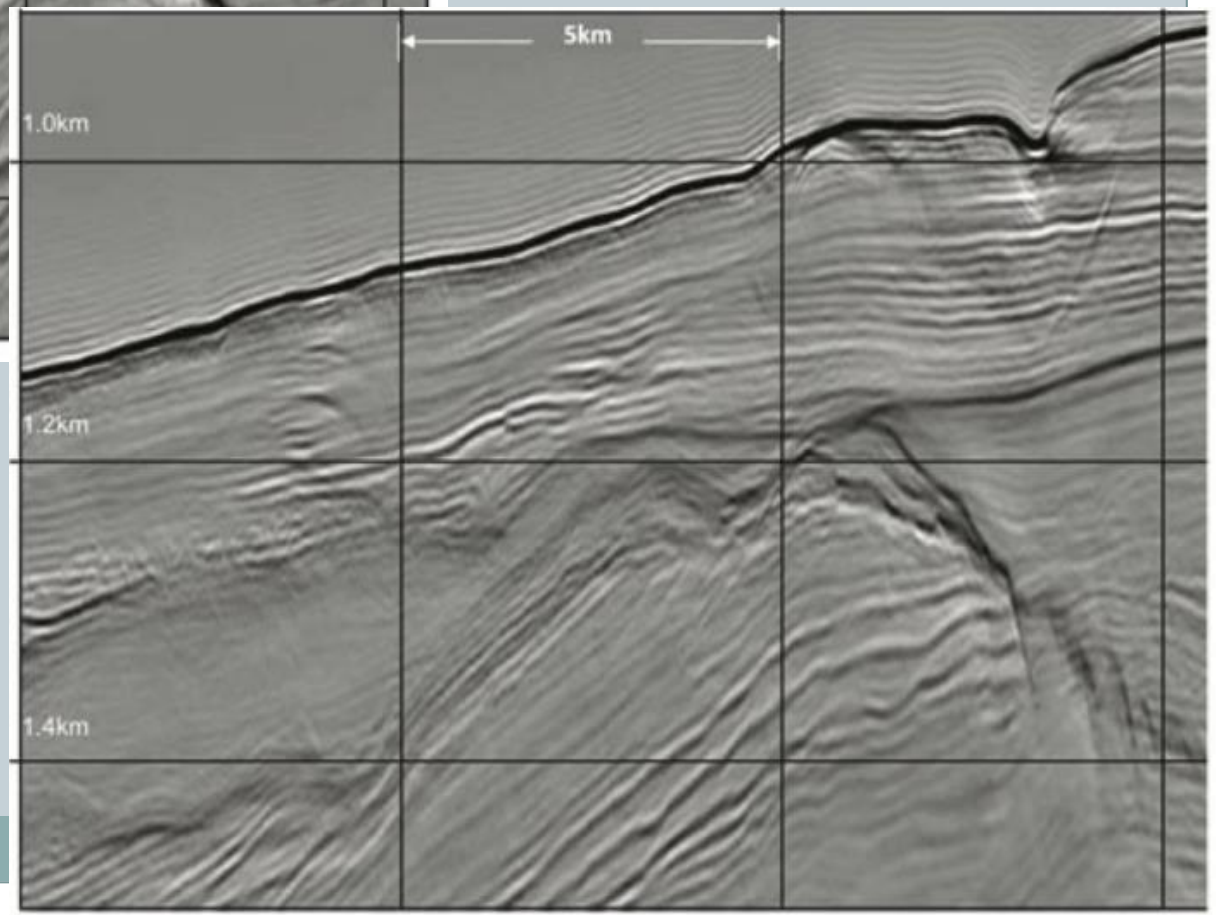
Extra High Frequencies

Conventional

Lower noise level thanks to deep tow solid streamer

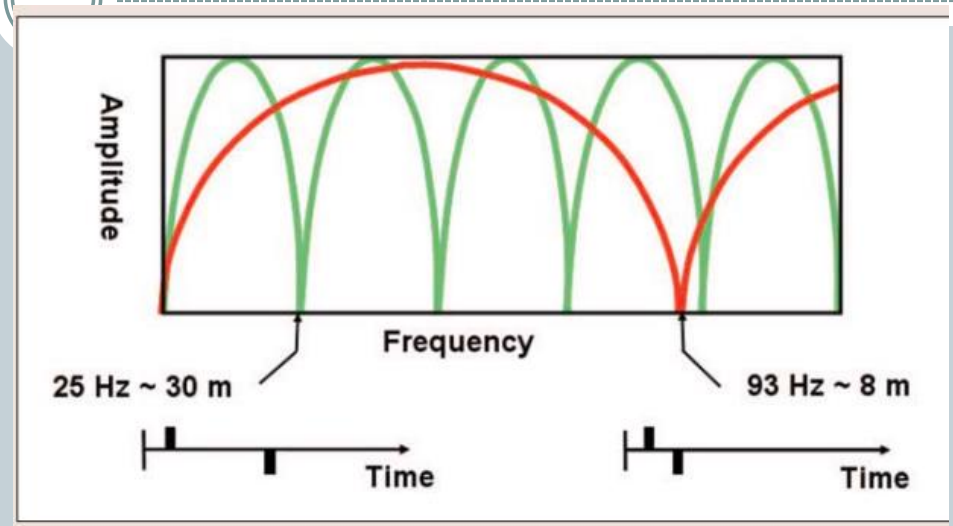


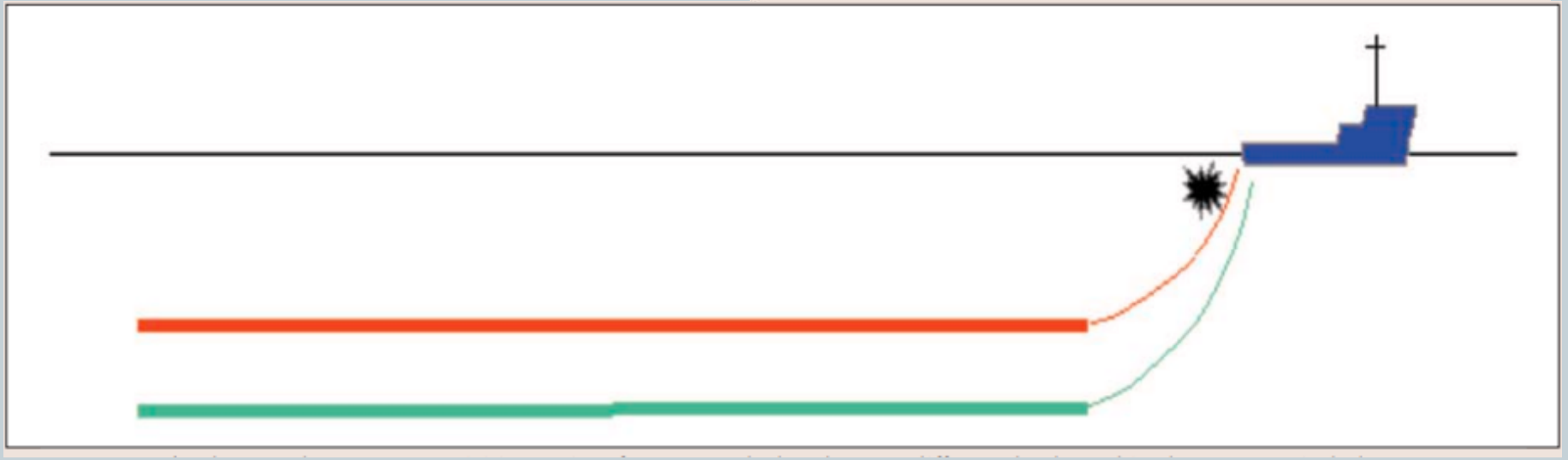
Variable depth streamer



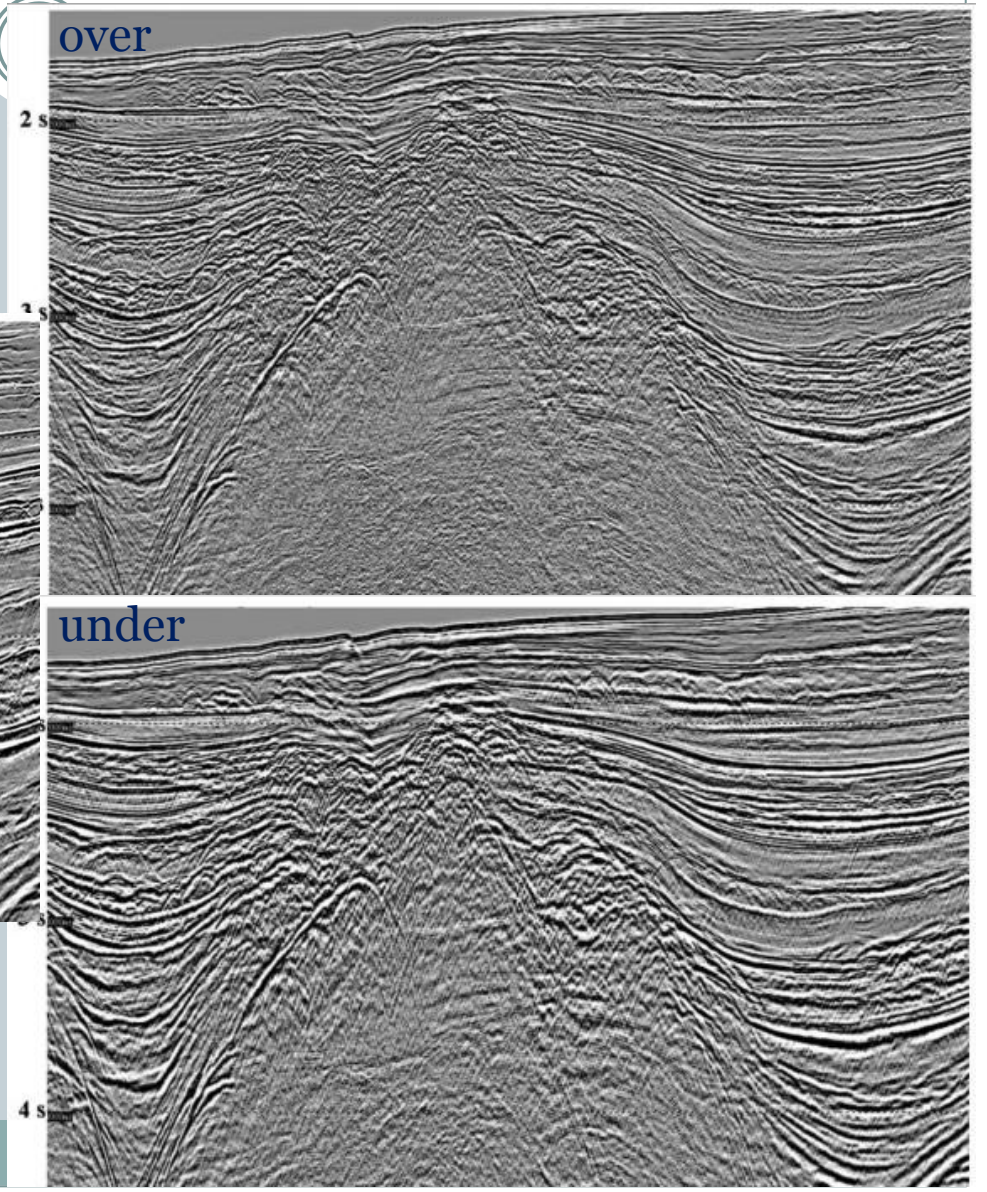
Variable depth streamer with broadband processing Joint Deconvolution

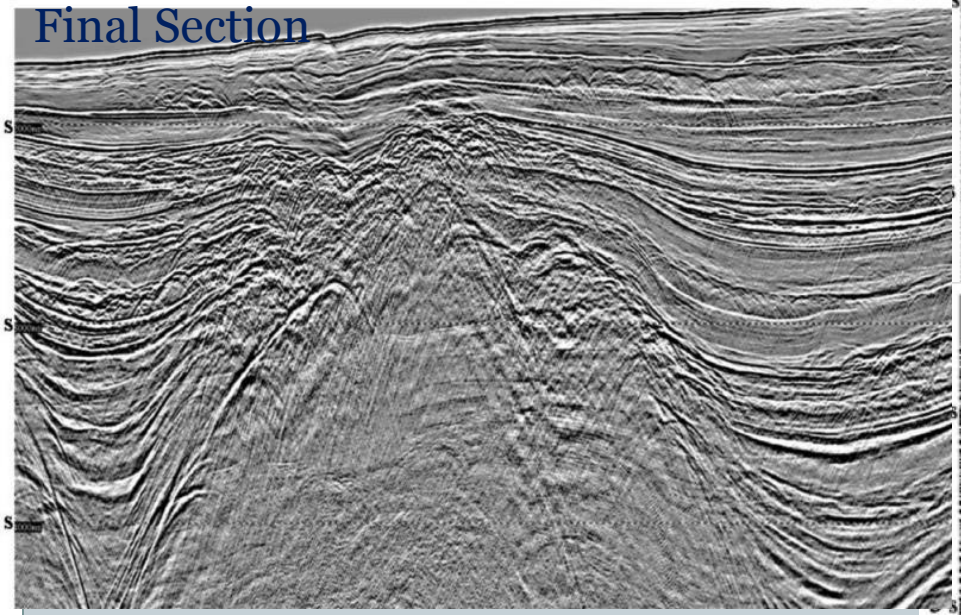
OVER_UNDER STREAMER





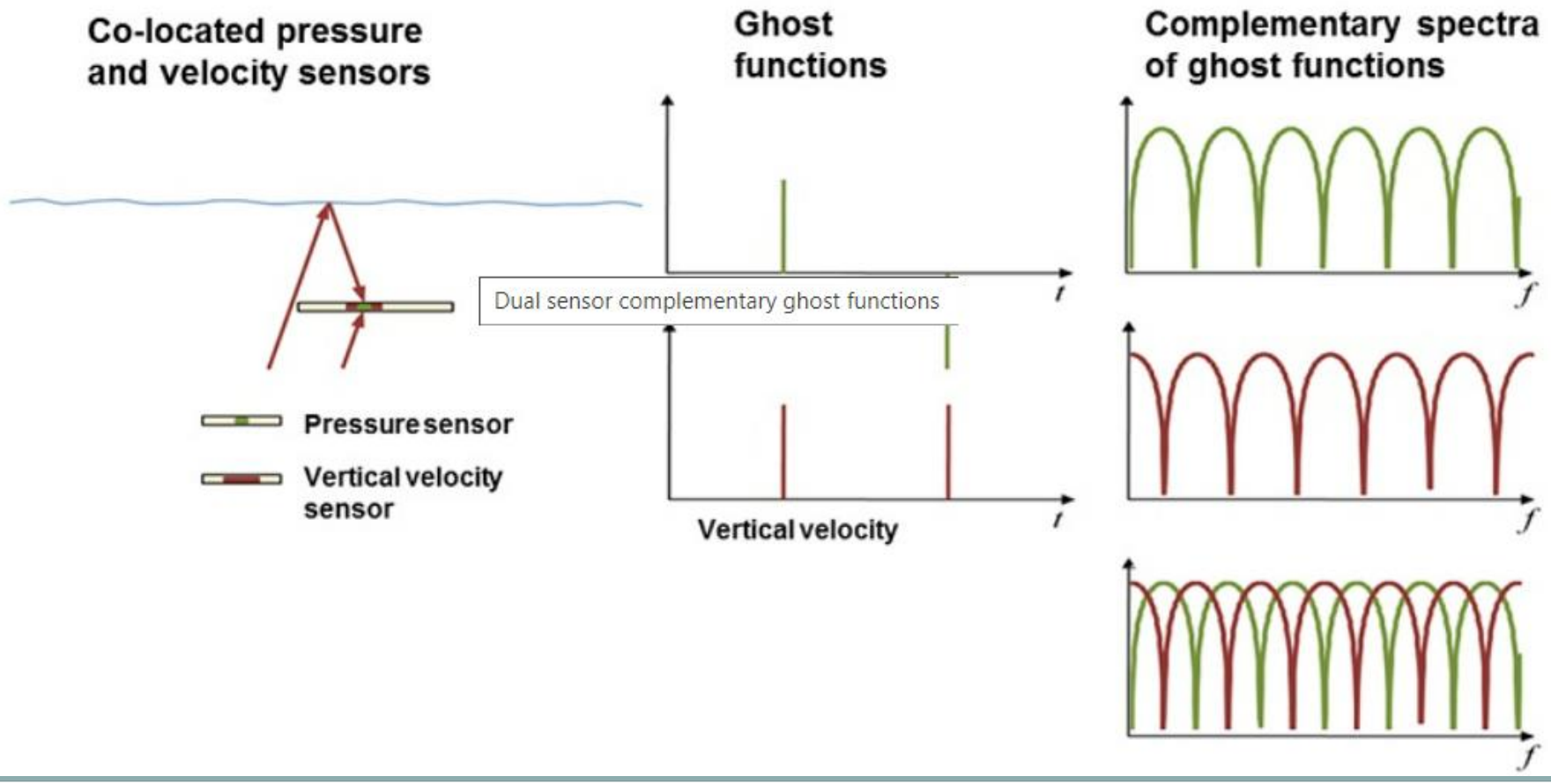
OVER_UNDER STREAMER





DUAL SENSOR STREAMER

By using the complementary properties of two sensors, GeoStreamer enables the removal of the receiver ghost by combining pressure measurements and velocity measurements (shown below).



DUAL SENSOR STREAMER

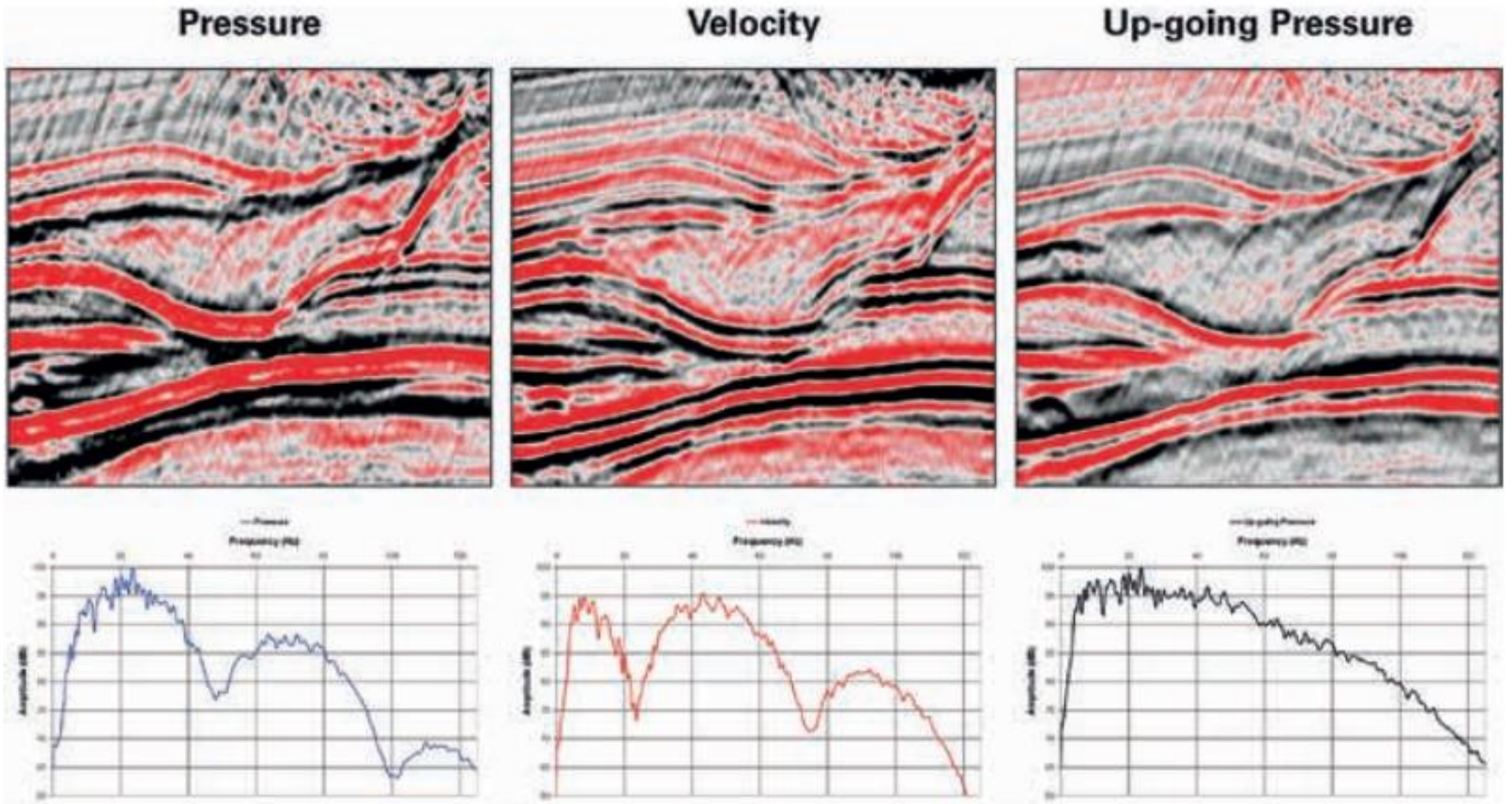
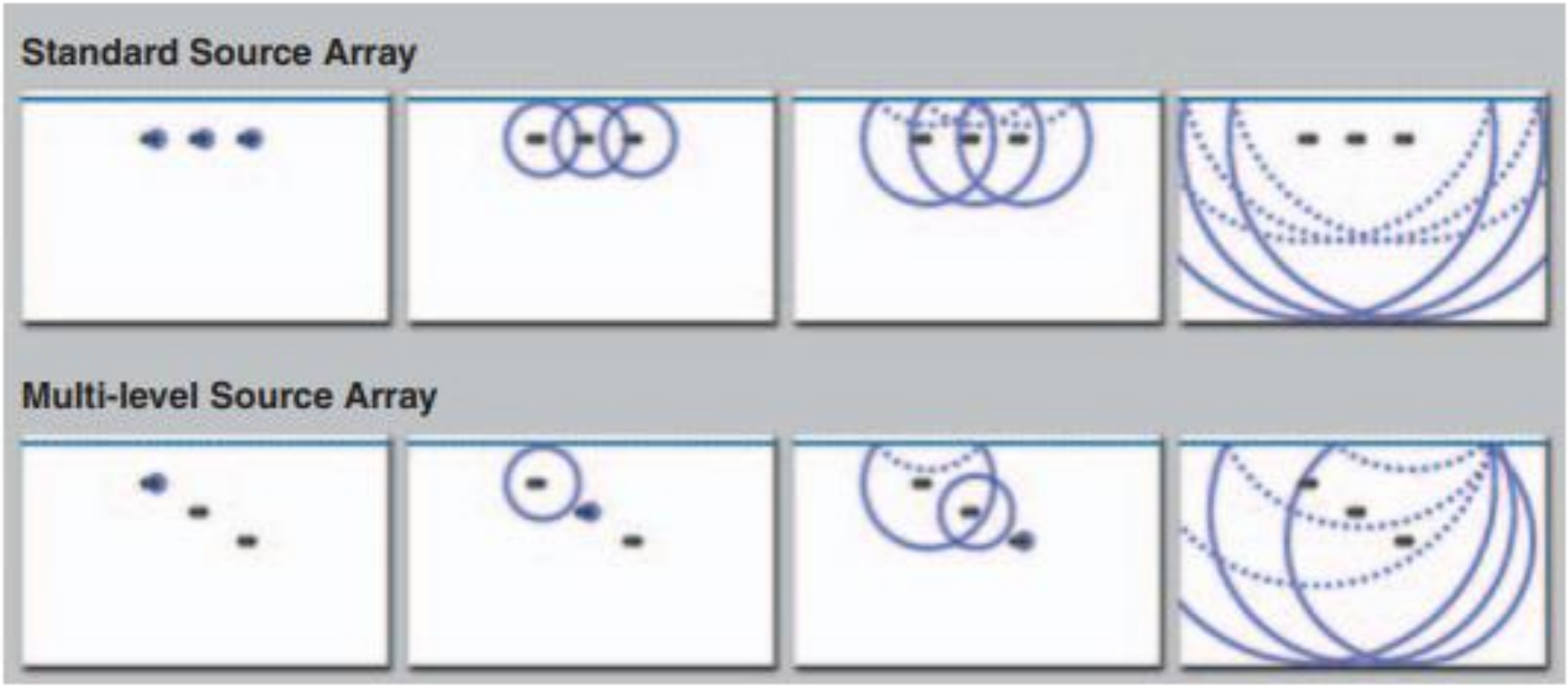
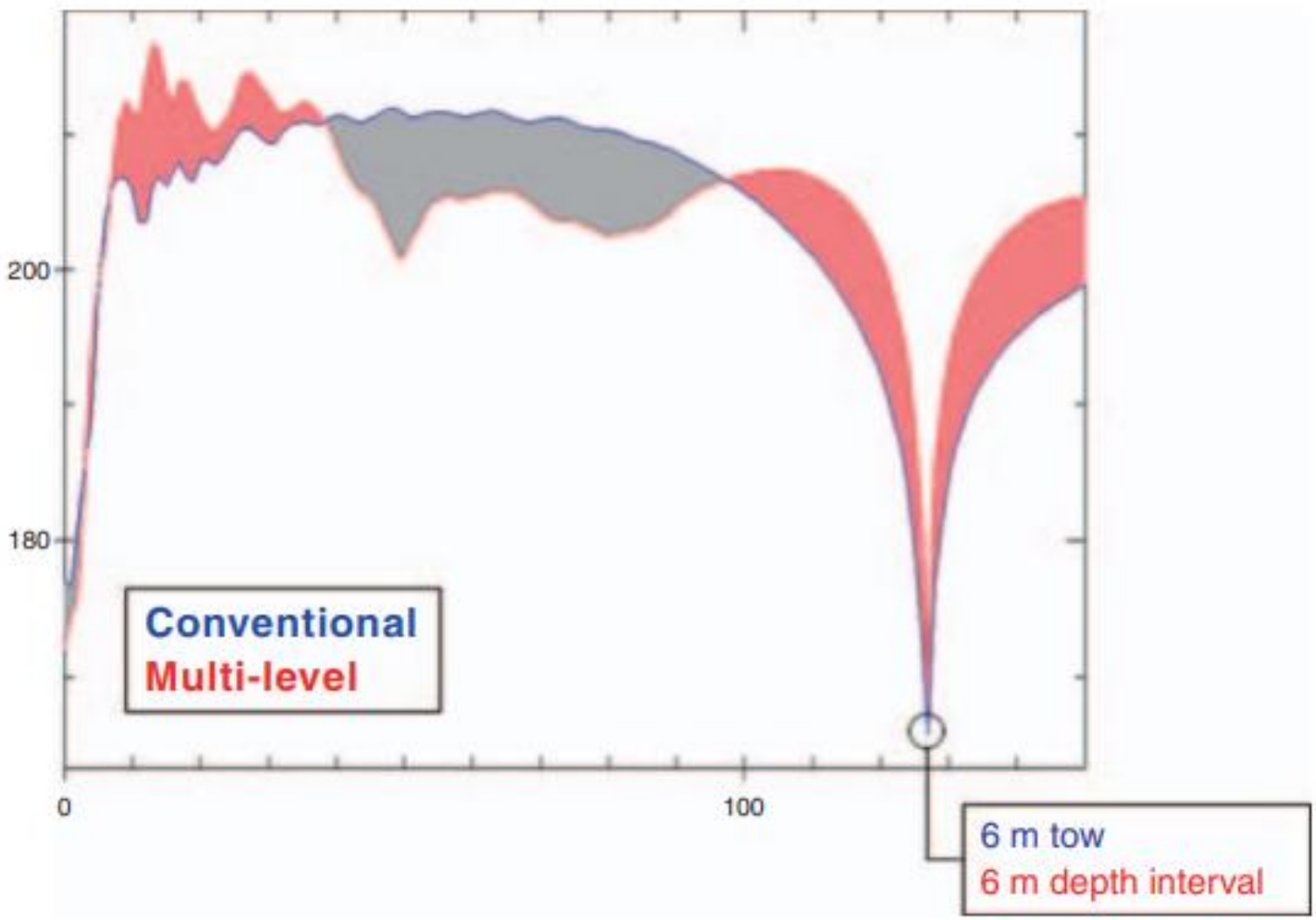


Figure 1 *Unmigrated stack comparison as shown in Carlson et al (2007). Note the complementary amplitude spectra for pressure vs. particle velocity. The images are from left to right, the pressure only result, the vertical particle velocity (or particle motion) only result and the up-going (de-ghosted) pressure wavefield derived from the pressure and velocity wavefields. The data shown in the example was acquired in 2007 with a streamer depth of 15 m.*

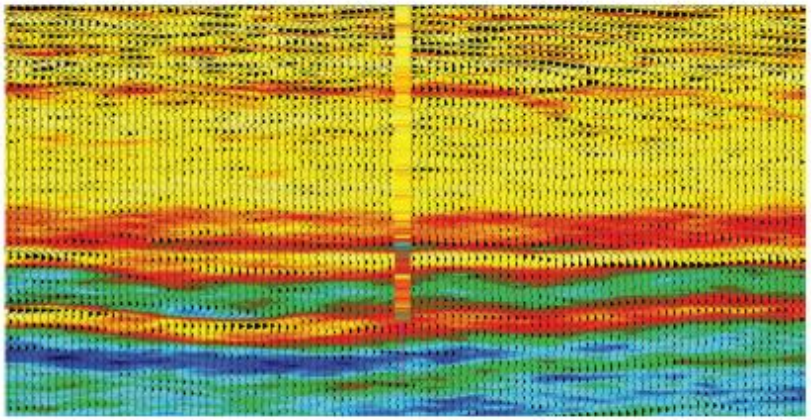
MULTILEVEL AIRGUN SOURCE



MULTILEVEL AIRGUN SOURCE



Broadband Processing for Conventional Marine Seismic



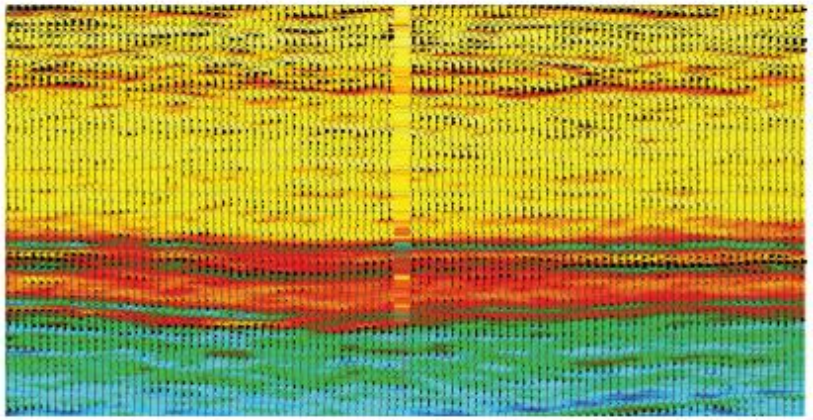
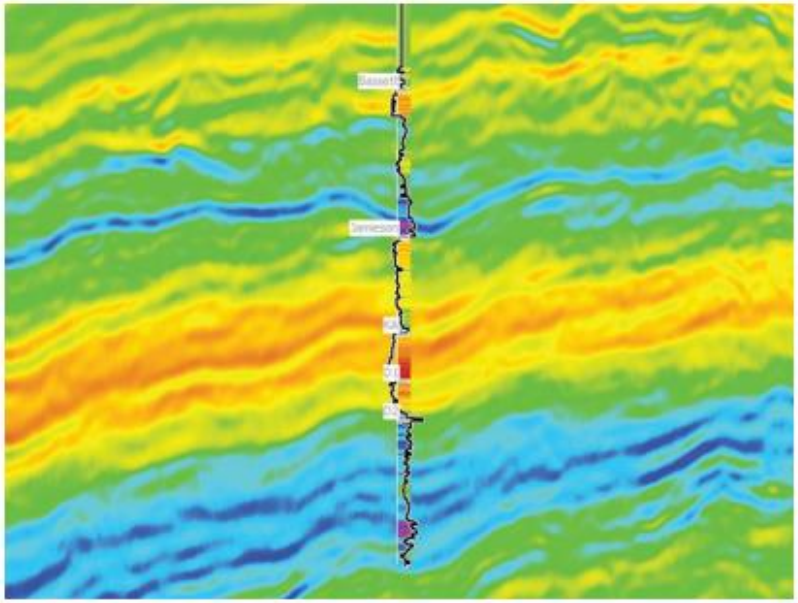
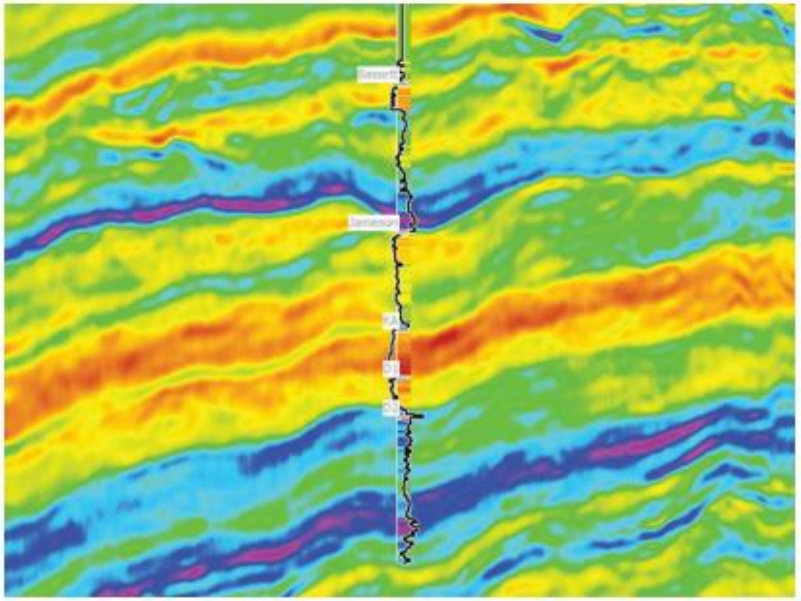


Figure on left. An image showing P-impedance from conventional processing with the inserted color column representing P-impedance at the wellbore. Notice the reasonably good well-tie. Figure on the right. P-impedance from WiBand processing. Notice the consistencies in color between the well log and the section. In addition, note the high impedance event becomes clearer and more consistent.





This pair of images show a seismic inversion example of a 2D line from deepwater Australia together with a well tie, "the ground truth," using conventional (figure on the left) versus WiBand processing (figure on the right). Note the better definition of the stratigraphy and improved well-tie of the data processed with WiBand. The data is courtesy of Searcher Seismic.

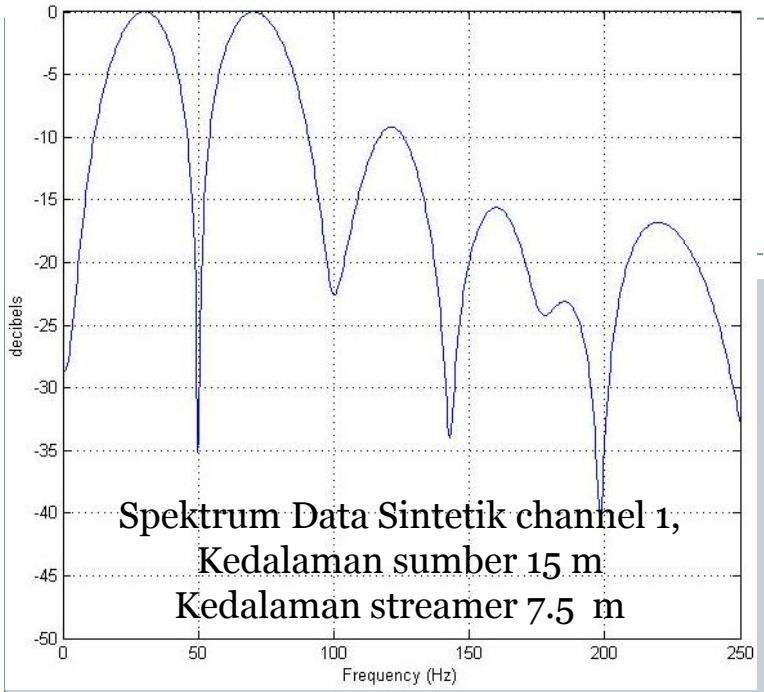
STUDI KASUS OVER UNDER STREAMER

Teknik Over-Under Streamer

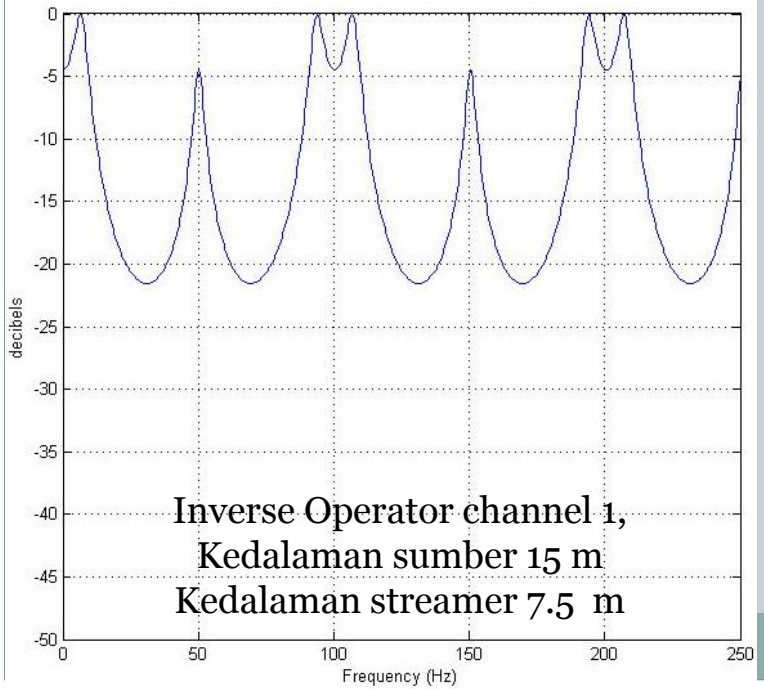
- Brink, 1987 mengaplikasikan teknik ini untuk mengatasi cuaca yang buruk.
- Posthumus(1993) dan Singh(1996) mengembangkan teknik ini untuk target dalam dan perolehan broadband seismik dengan pengolahan combined mode yaitu penjumlahan trace seismik dari setiap streamer setelah koreksi statik.

Metoda Penelitian:
Deghosting

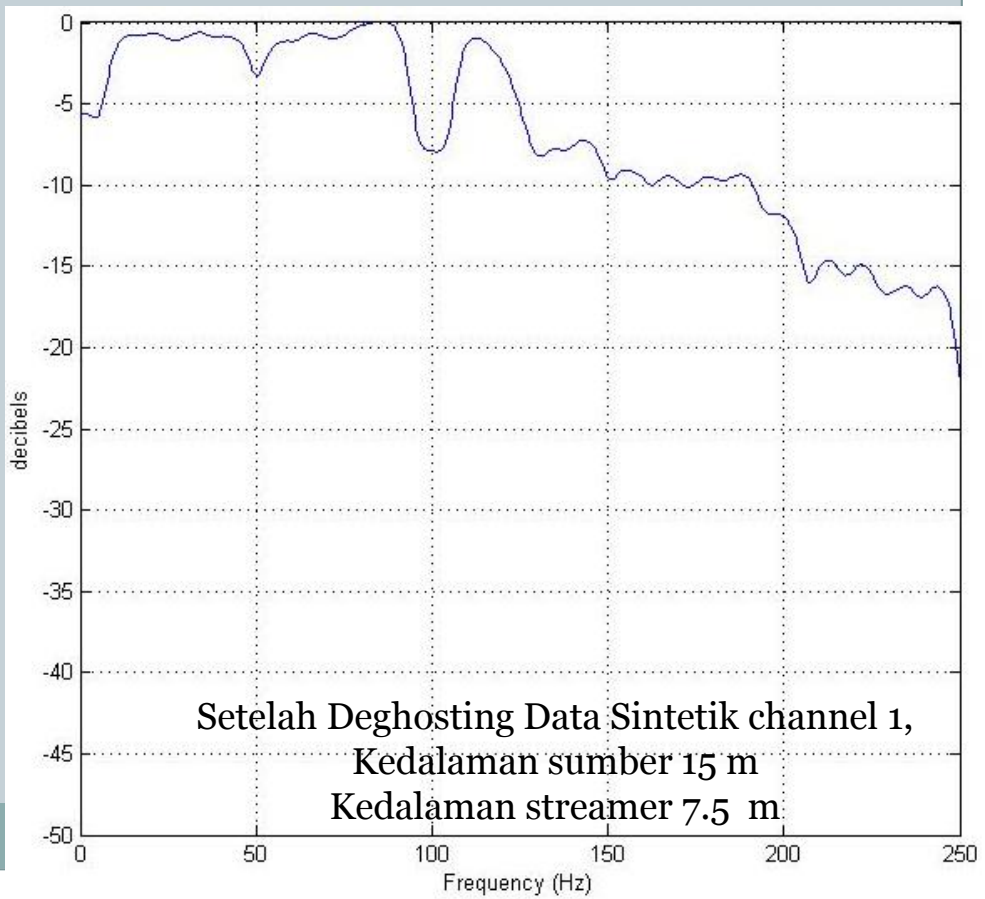
Teknik deghosting dilakukan dengan mengalikan data dan inverse operator dalam domain frekuensi



Spektrum Data Sintetik channel 1,
Kedalaman sumber 15 m
Kedalaman streamer 7.5 m

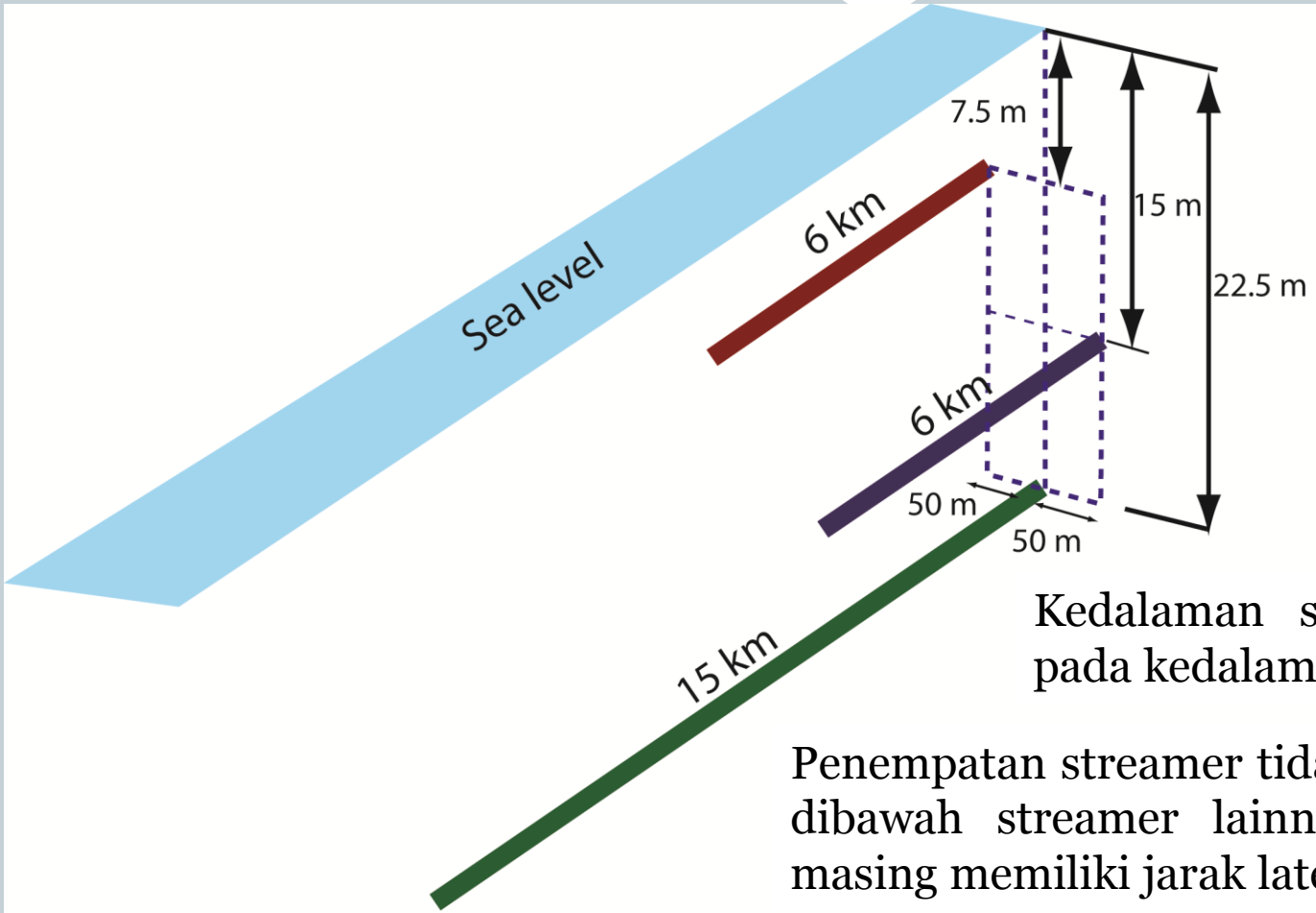


Inverse Operator channel 1,
Kedalaman sumber 15 m
Kedalaman streamer 7.5 m



Setelah Deghosting Data Sintetik channel 1,
Kedalaman sumber 15 m
Kedalaman streamer 7.5 m

Teknik Over-Under Streamer



Kedalaman sumber ditempatkan pada kedalaman 15 meter

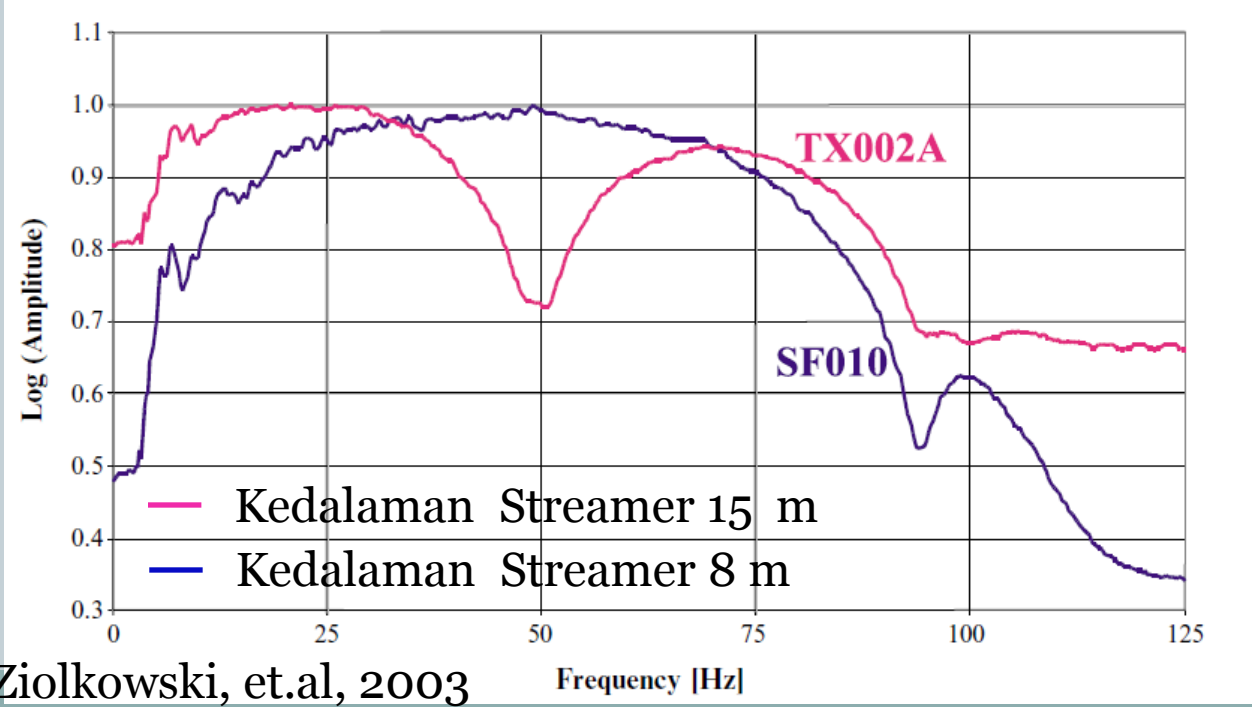
Penempatan streamer tidak tepat ditempatkan dibawah streamer lainnya, namun masing-masing memiliki jarak lateral 50 meter

Hananto et al. Figure 3

Konfigurasi teknik over – under streamer tahun 2009

Teknik Over-Under Streamer

- Teknik over-under merupakan teknik broadband seismik, Teknik ini dapat mereduksi atau mengeliminasi ghost notch apabila konfigurasi yang digunakan tepat.



Ziolkowski, et.al, 2003

Metode Combined Mode dan Combined Mode dengan Deghosting

- Metode combined mode merupakan metode pengolahan data over-under streamer dengan cara menjumlahkan setiap trace seismik dari ketiga kedalaman streamer yang berbeda(setiap shot gather) dengan terlebih dahulu dilakukan koreksi statik.
- Metoda combined mode + deghosting adalah metoda combined mode dengan terlebih dahulu dilakukan deghosting terhadap ketiga data seismik yang berbeda kedalaman streamernya.

Data

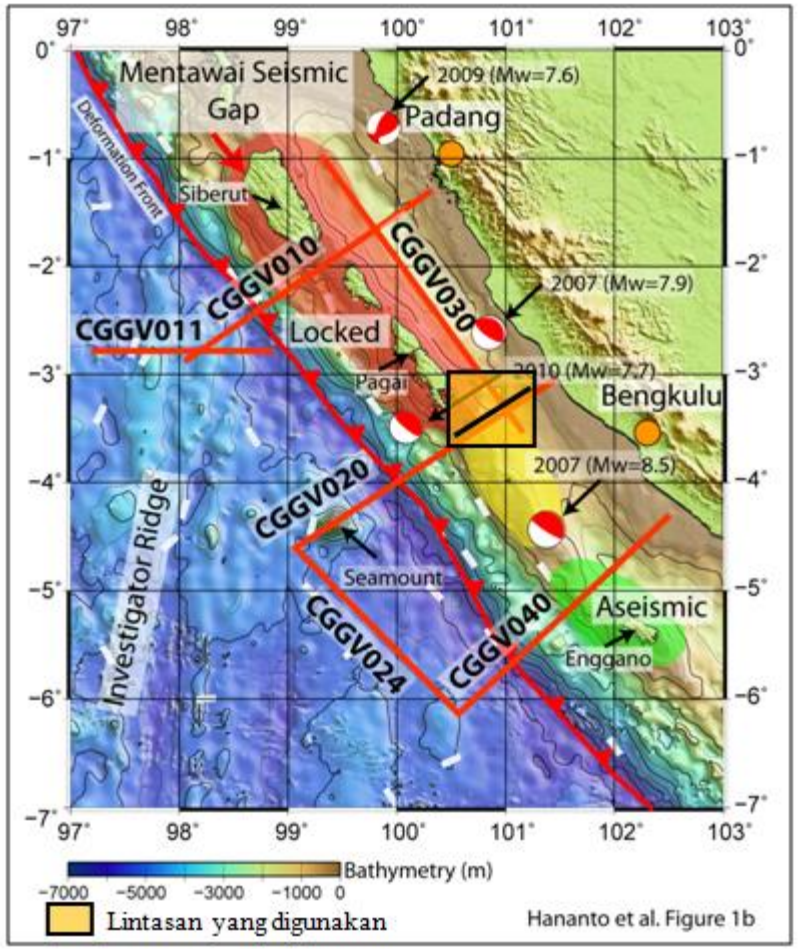
Data terdiri dari data sintetik dan data lapangan.

Data seismik dengan teknik over –under streamer dengan konfigurasi : Terdiri dari 3 streamer masing-masing dengan bentangan 6 km, 6 km dan 15 km dan kedalaman masing-masing streamer 7.5, 15 dan 22.5 meter.

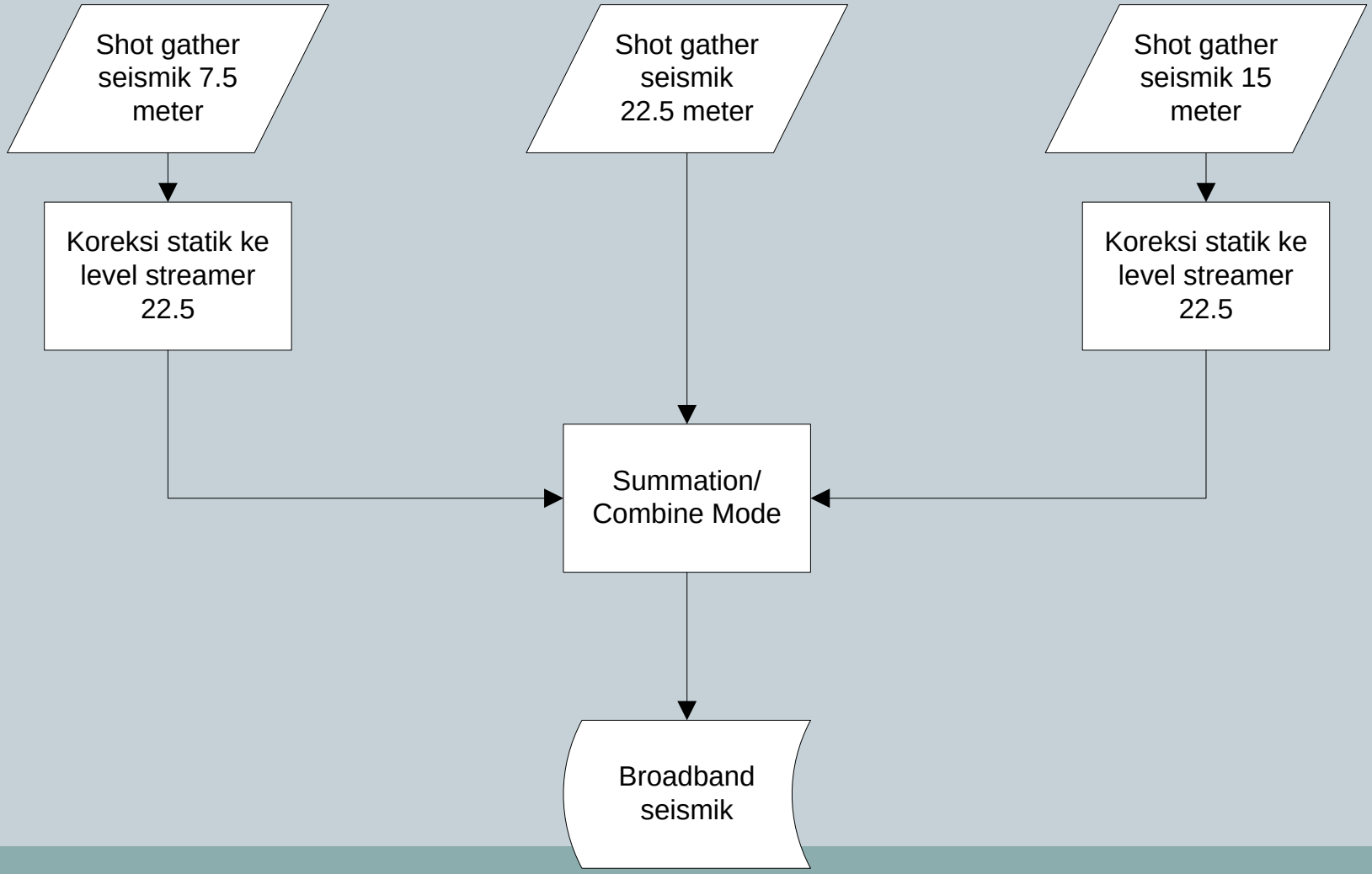
Interval receiver : 12.5 meter
Interval shot : 50 meter

Kedalaman sumber 15 meter

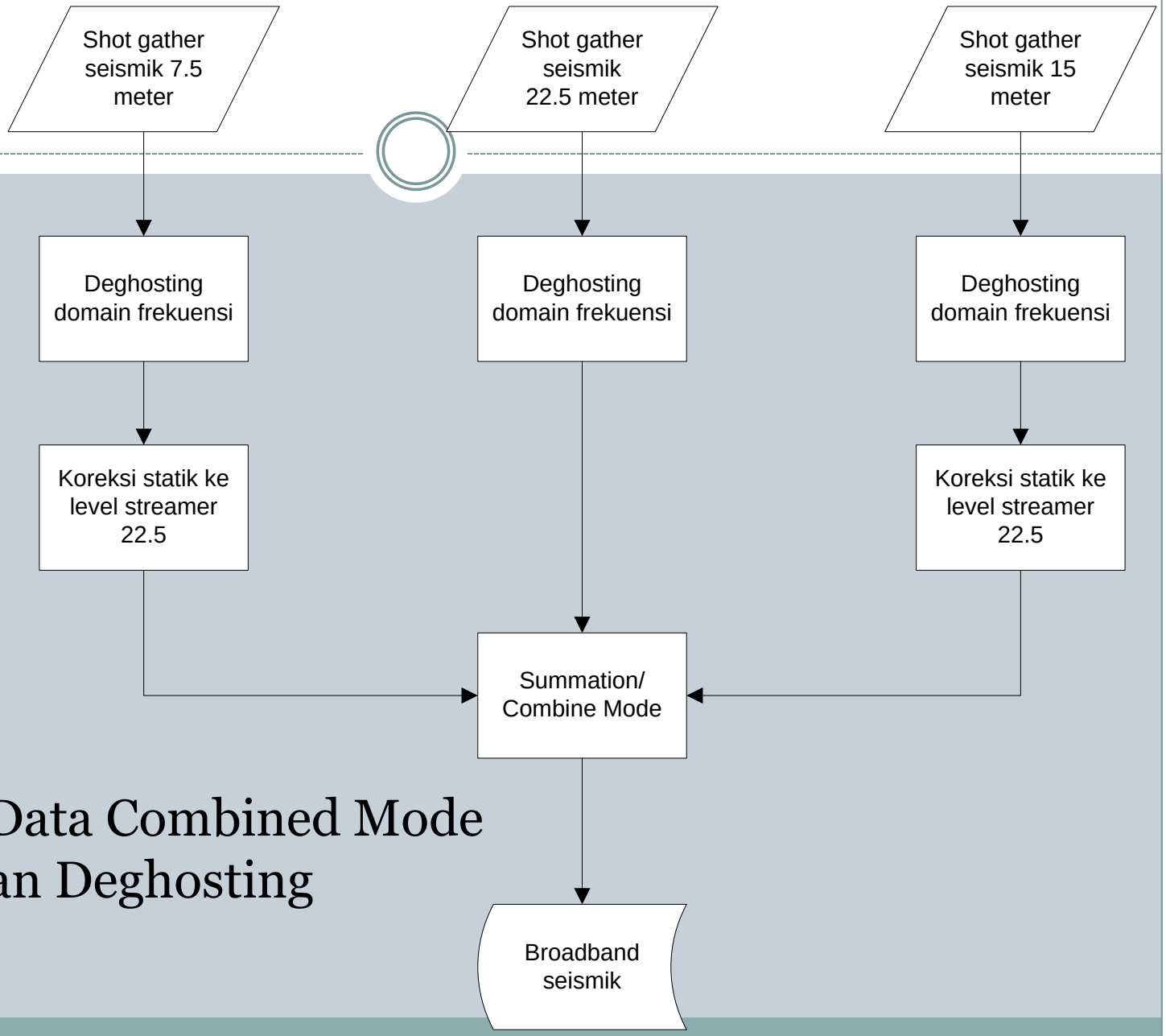
Untuk data sintetik konfigurasi mengikuti data lapangan hanya menggunakan 48 channel.

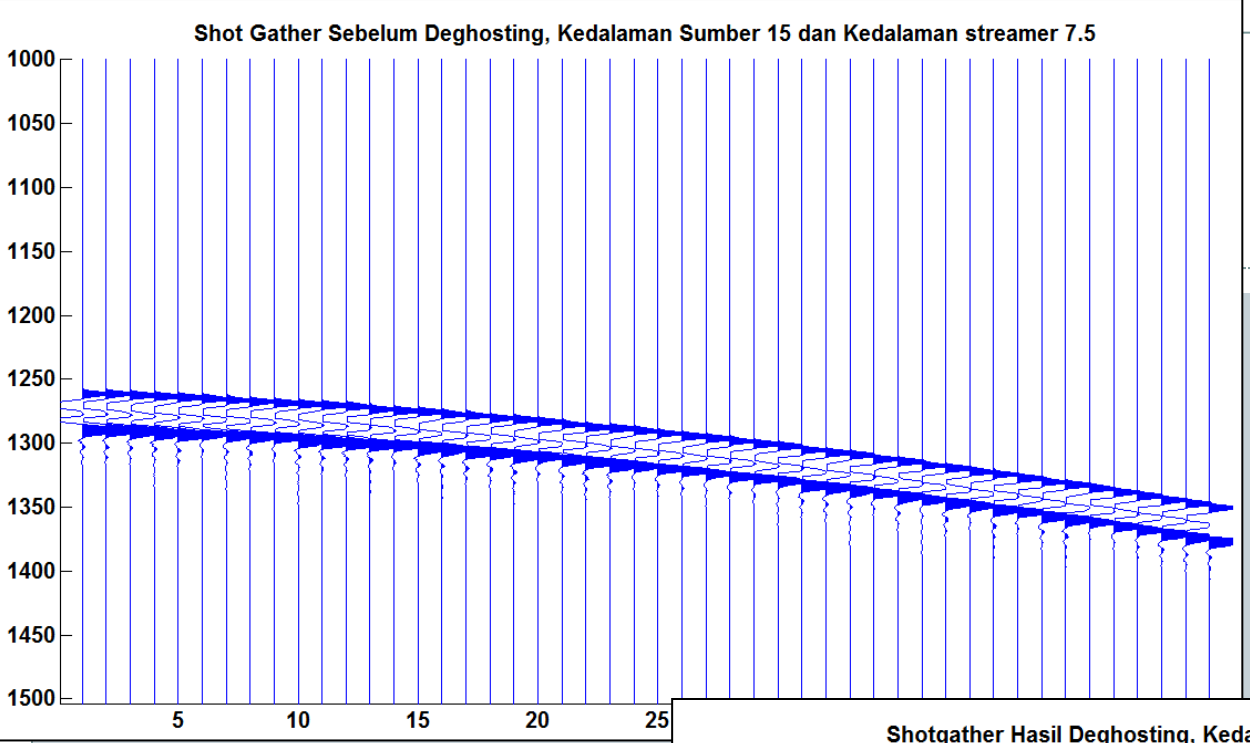


Pengolahan Data Combined Mode



Pengolahan Data Combined Mode dengan Deghosting

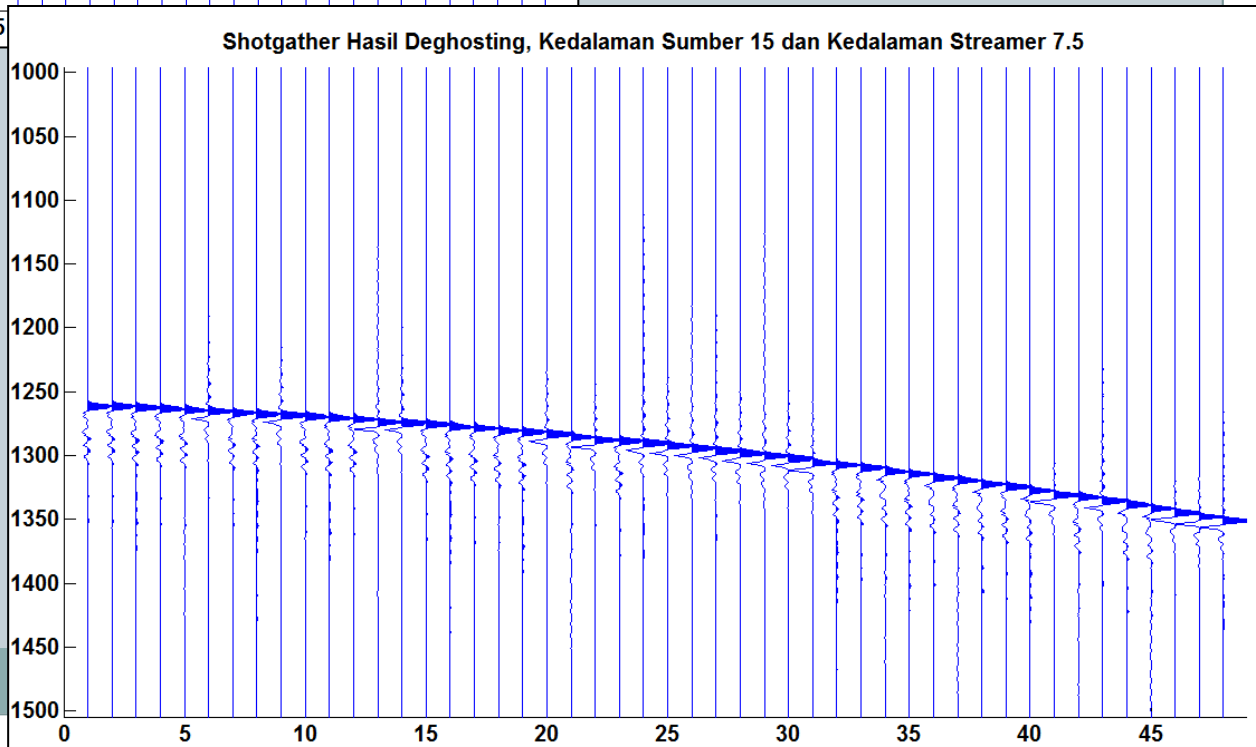


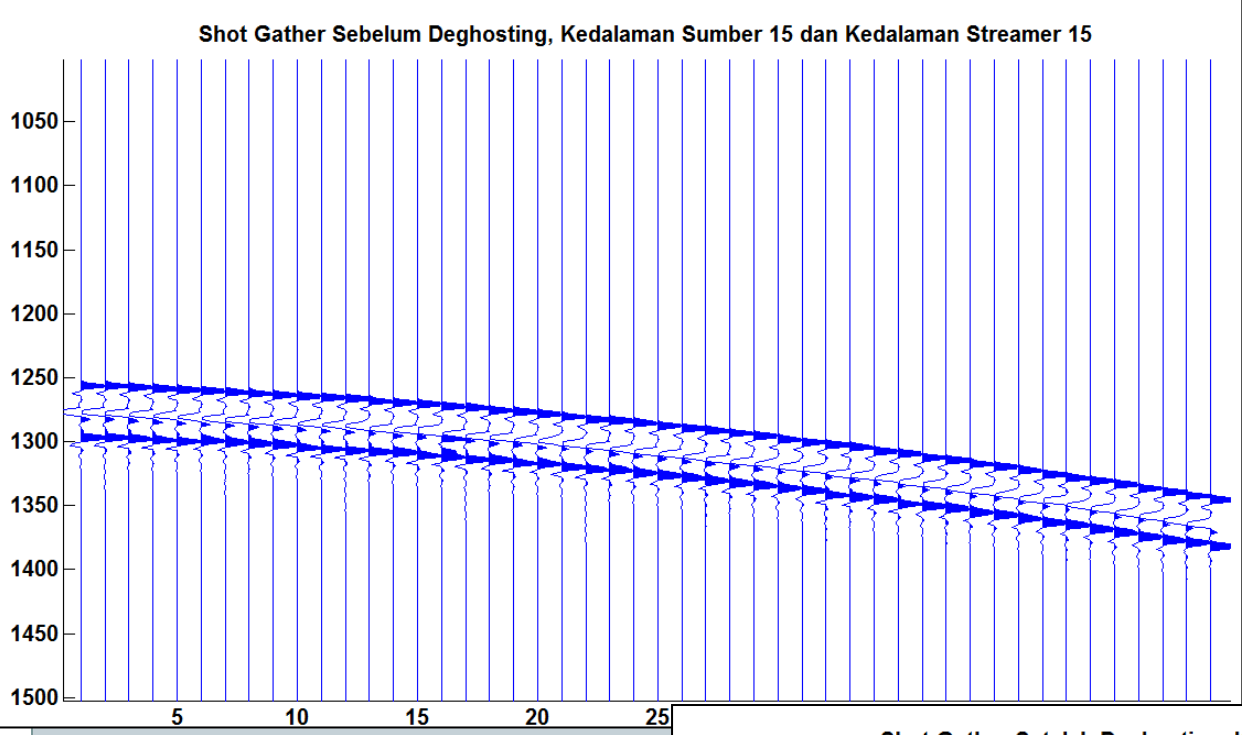


Hasil Deghosting : Data Sintetik

Atas : Shot gather, Sebelum deghosting, kedalaman sumber 15 dan kedalaman streamer 7.5

Bawah : Shot gather setelah deghosting, kedalaman sumber 15 dan kedalaman streamer 7.5

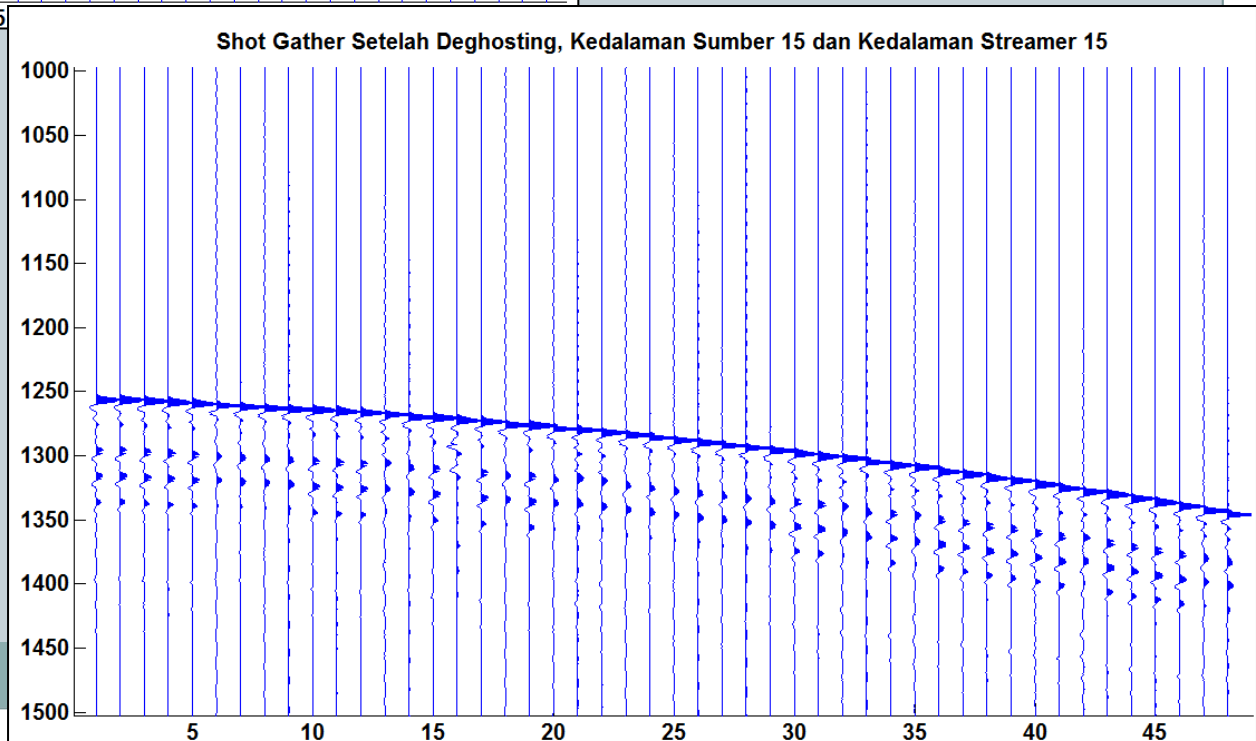


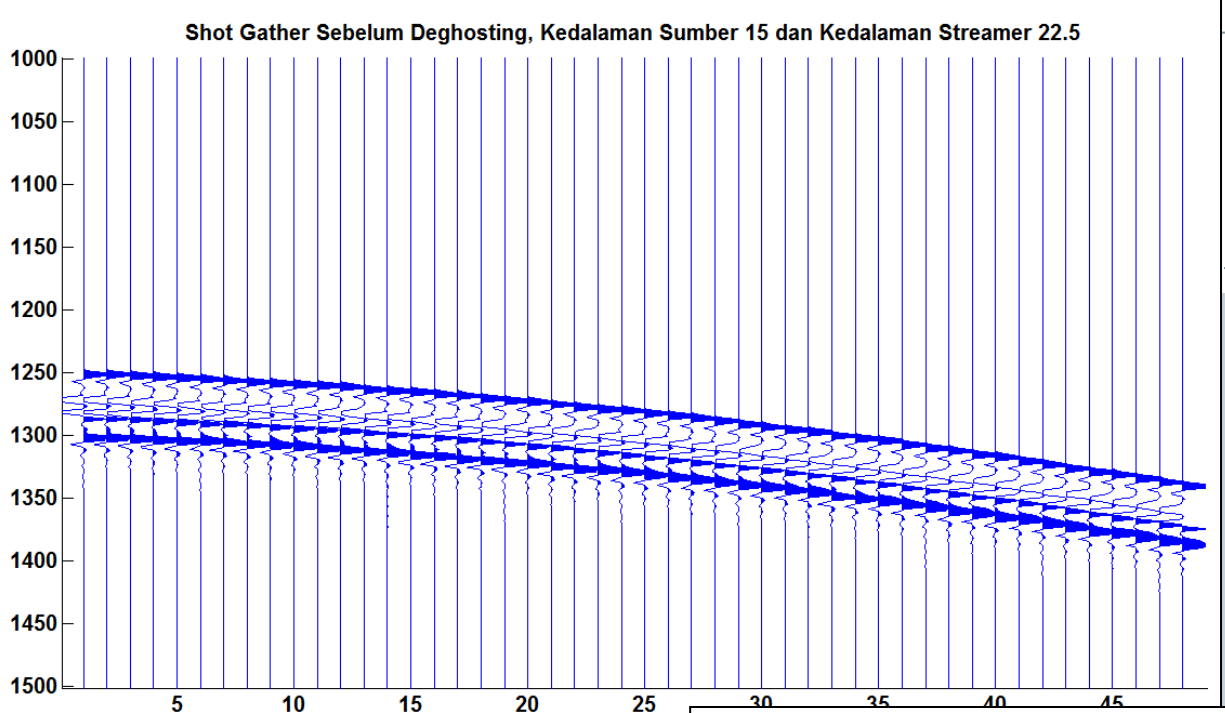


Hasil Deghosting : Data Sintetik

Atas : Shot gather, sebelum deghosting, kedalaman sumber 15 dan kedalaman streamer 15

Bawah : Shot gather setelah deghosting, kedalaman sumber 15 dan kedalaman streamer 15

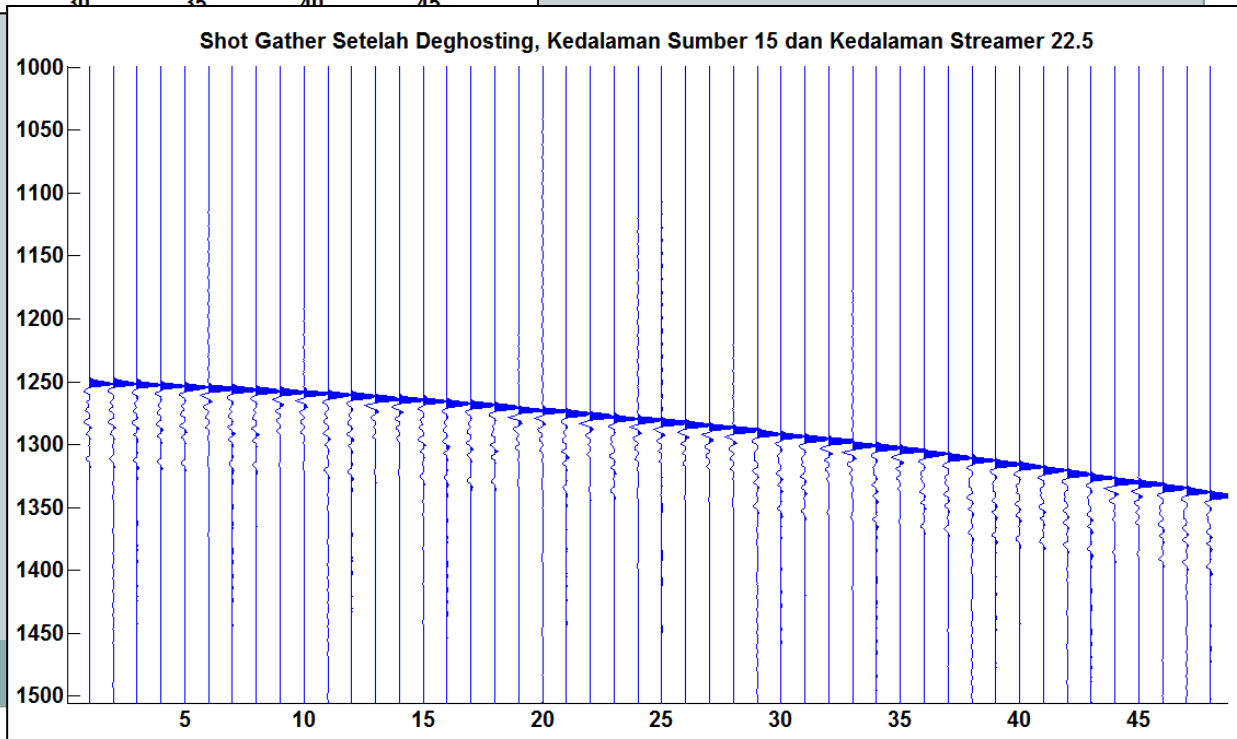


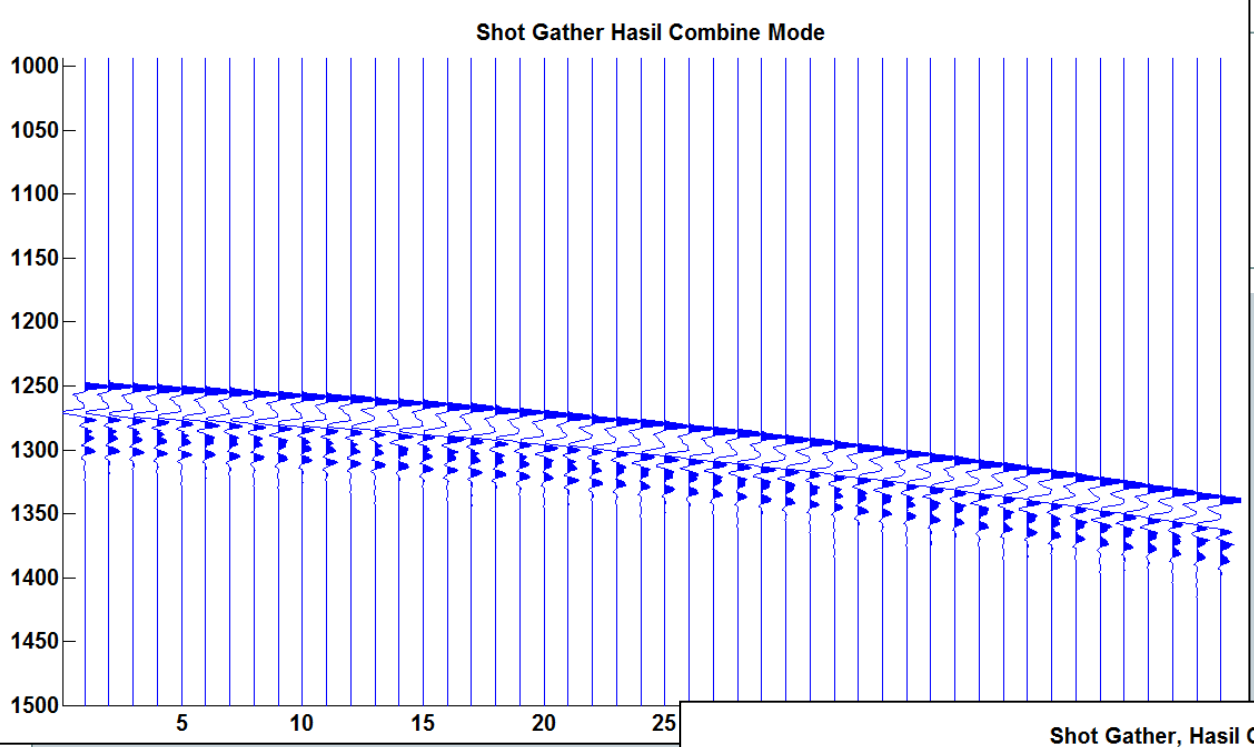


Hasil Deghosting : Data Sintetik

Atas : Shot gather, sebelum deghosting, kedalaman sumber 15 dan kedalaman streamer 22.5

Bawah : Shot gather setelah deghosting, kedalaman sumber 15 dan kedalaman streamer 22.5

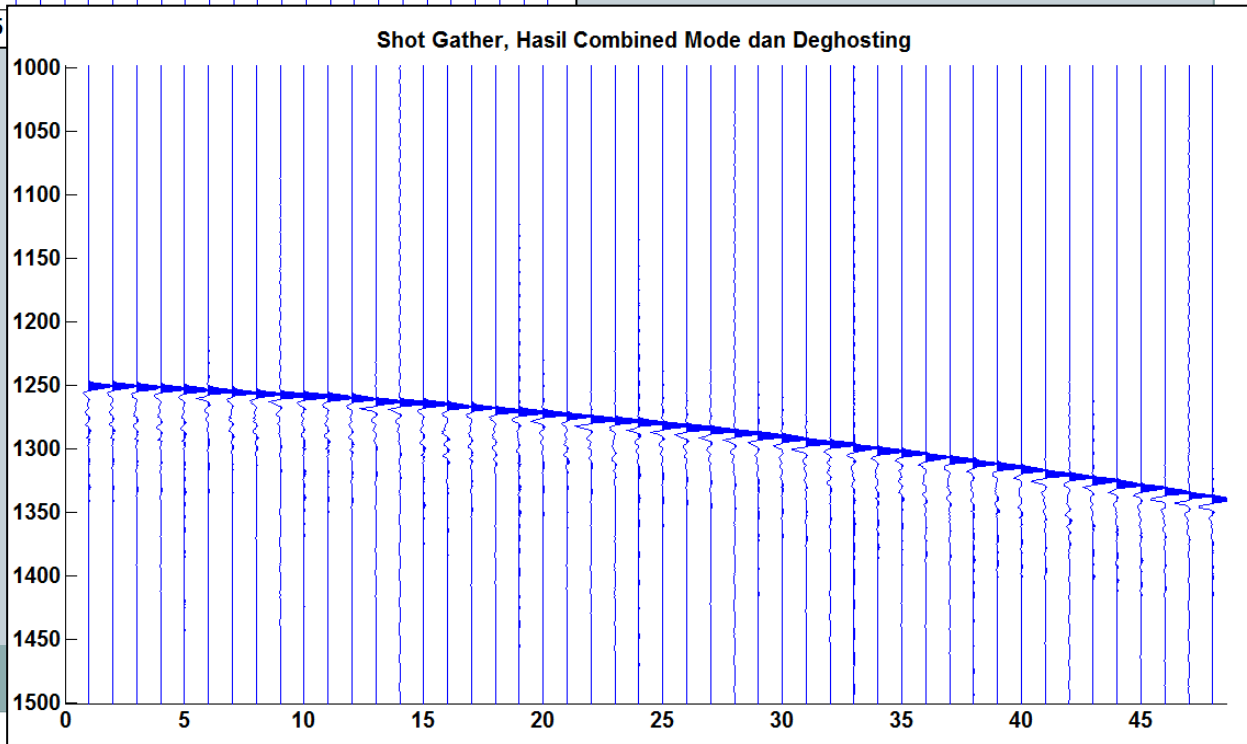




Hasil Deghosting : Data Sintetik

Atas : Shot gather, hasil combined mode

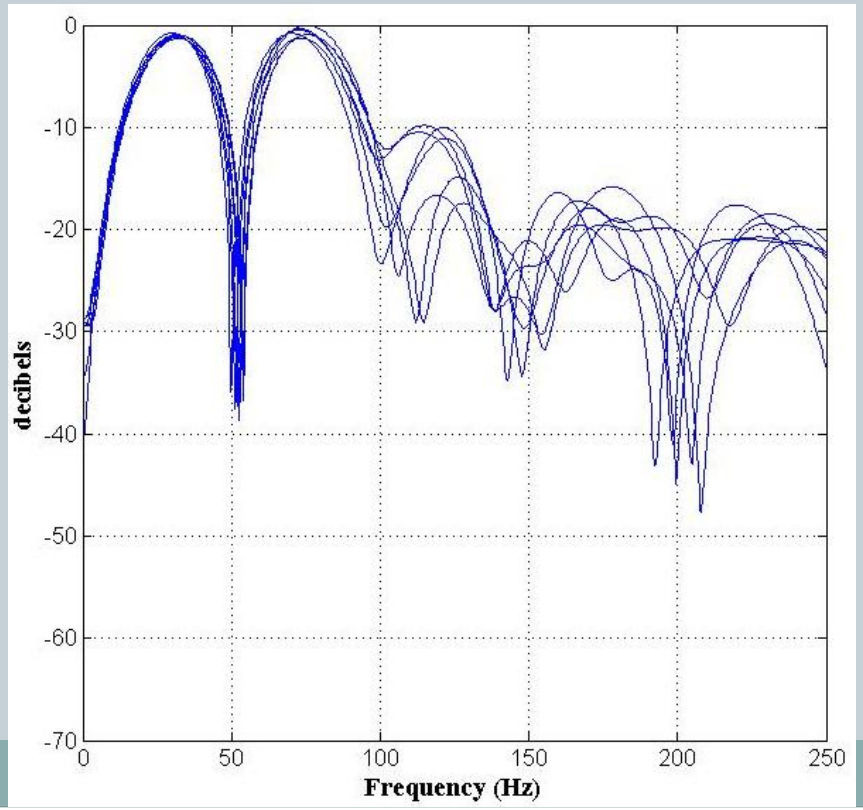
Bawah : Shot gather hasil combined mode dan deghosting

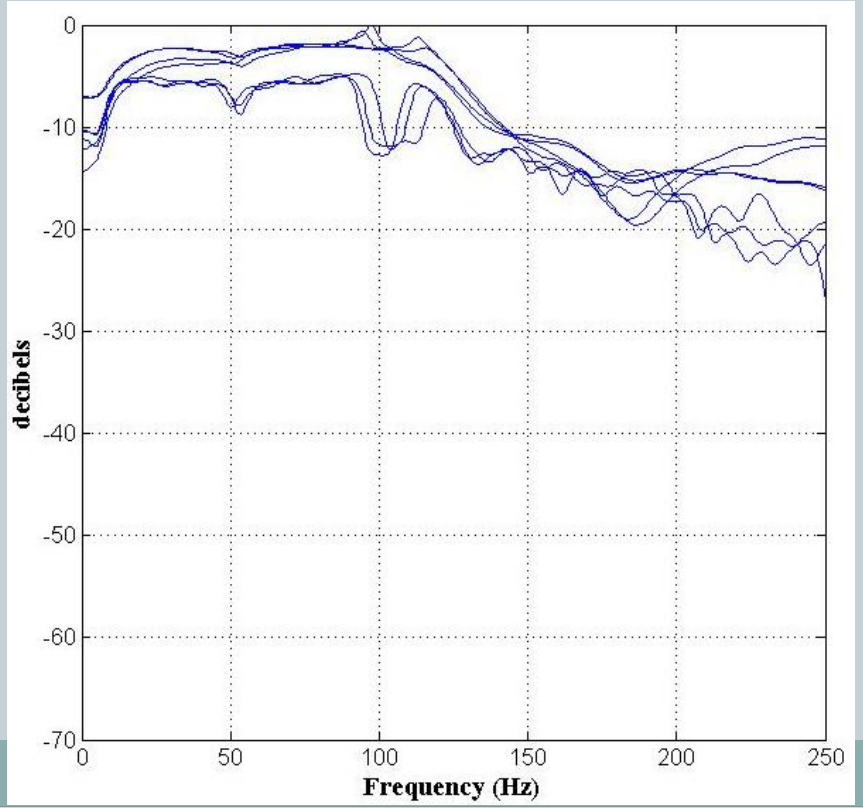


Hasil Deghosting: Spektrum Frekuensi Data Sintetik

Spektrum Frekuensi data sintetik (kiri)sebelum deghosting dan (kanan)sesudah deghosting Kedalaman sumber 15 dan kedalaman streamer 7.5 meter.

Efek ghost notch sudah tereliminasi oleh proses deghosting.

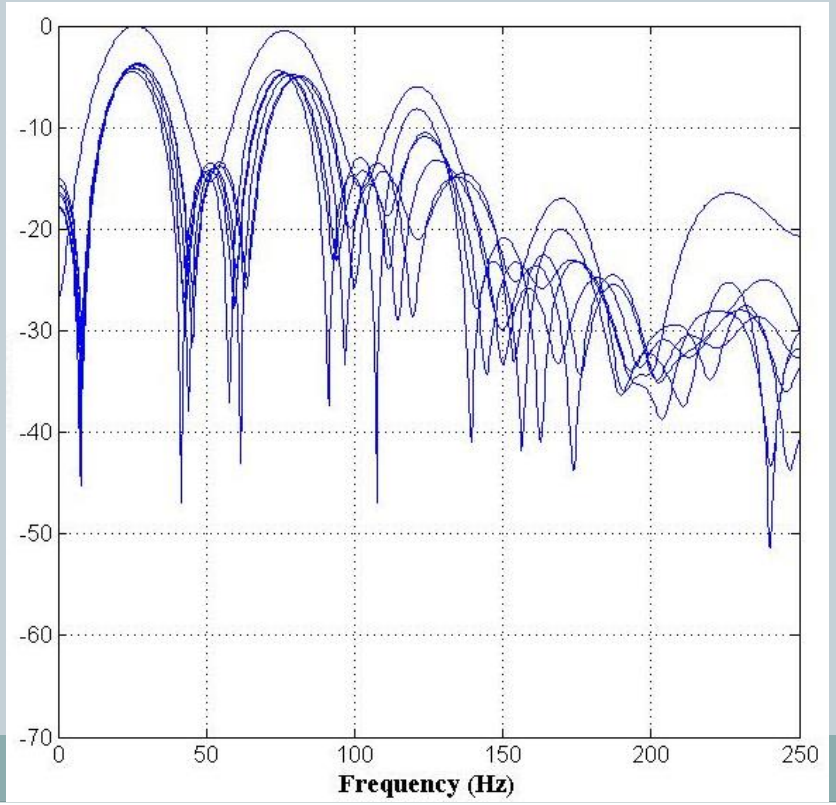


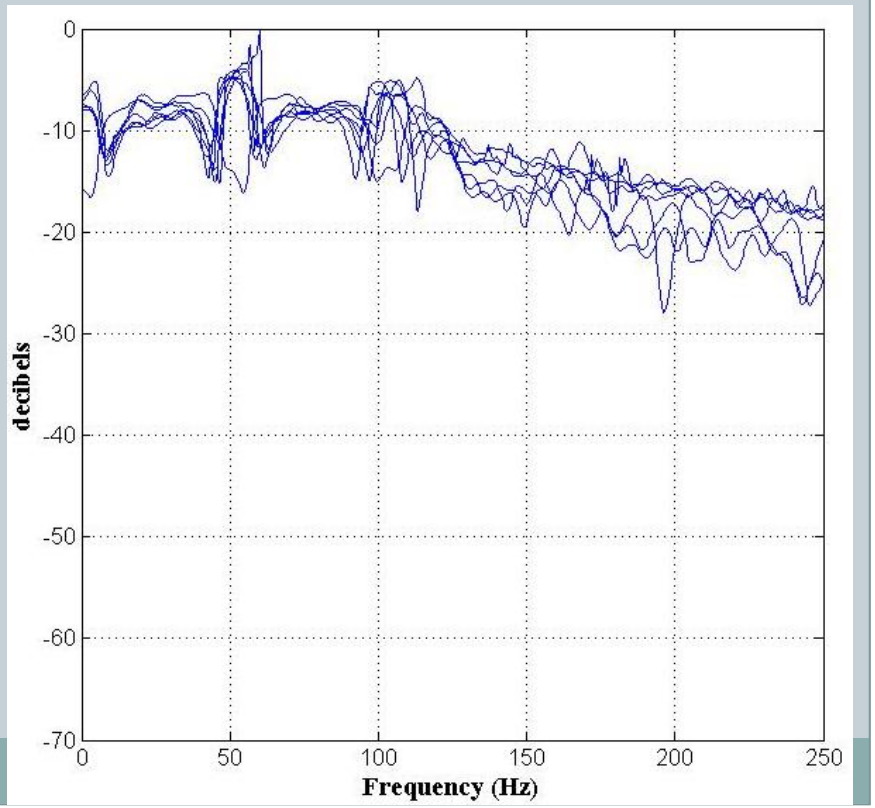


Hasil Deghosting: Spektrum Frekuensi Data Sintetik

Spektrum Frekuensi data sintetik (kiri)sebelum deghosting dan (kanan)sesudah deghosting Kedalaman sumber 15 dan kedalaman streamer 15 meter.

Efek ghost notch sudah tereliminasi oleh proses deghosting.





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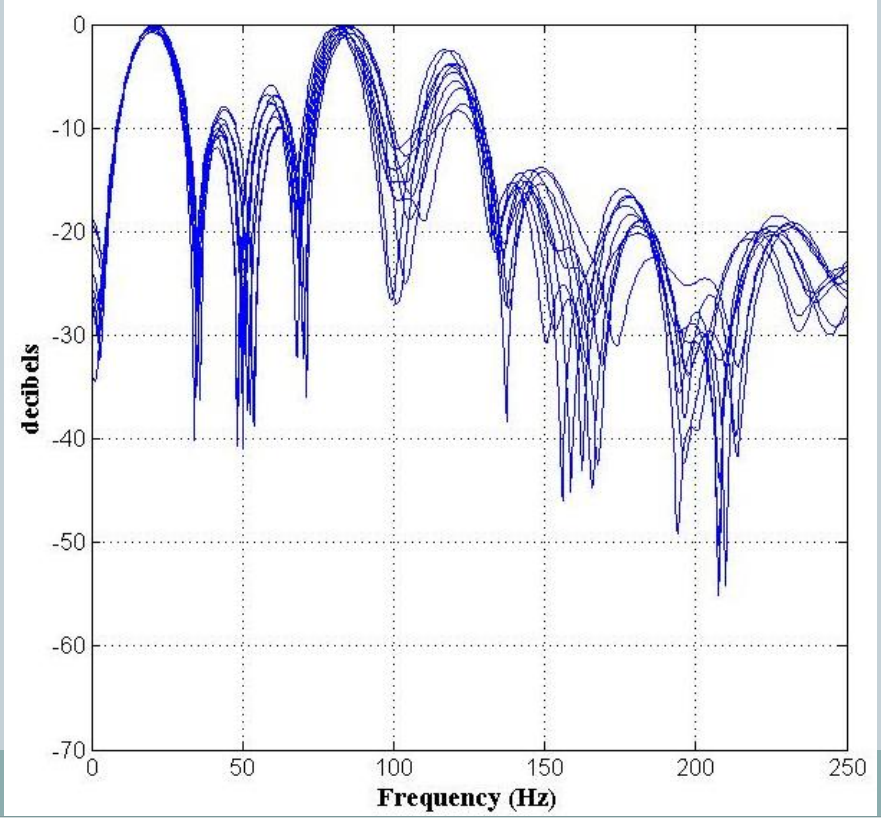
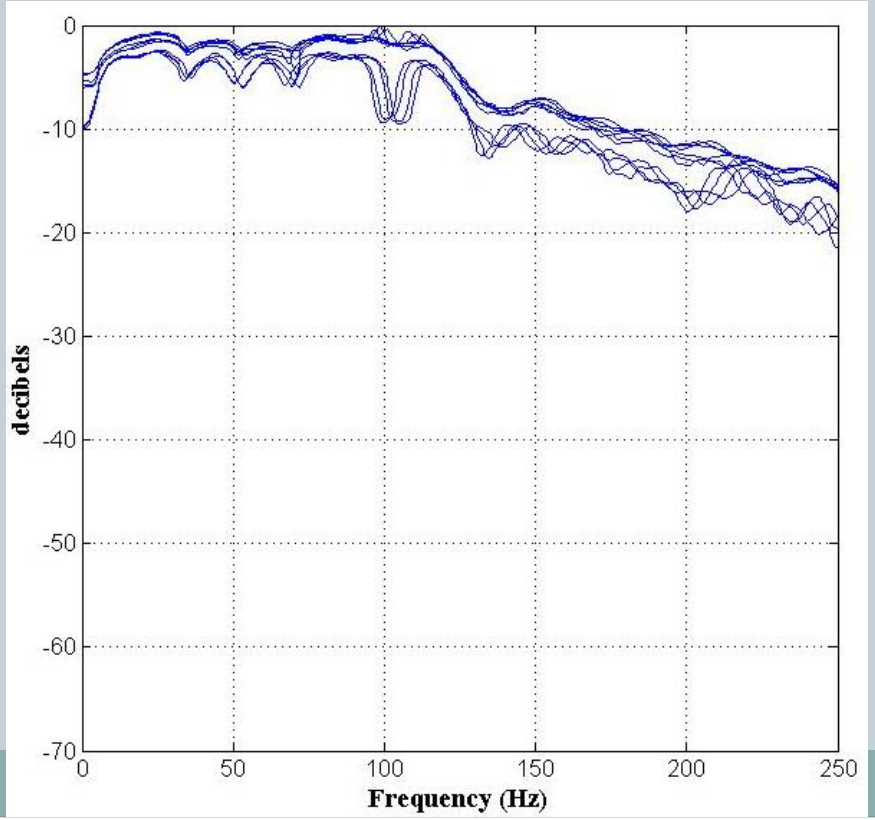
Spektrum Frekuensi data sintetik (kiri)sebelum deghosting dan (kanan)sesudah deghosting Kedalaman sumber 15 dan kedalaman streamer 22.5 meter.

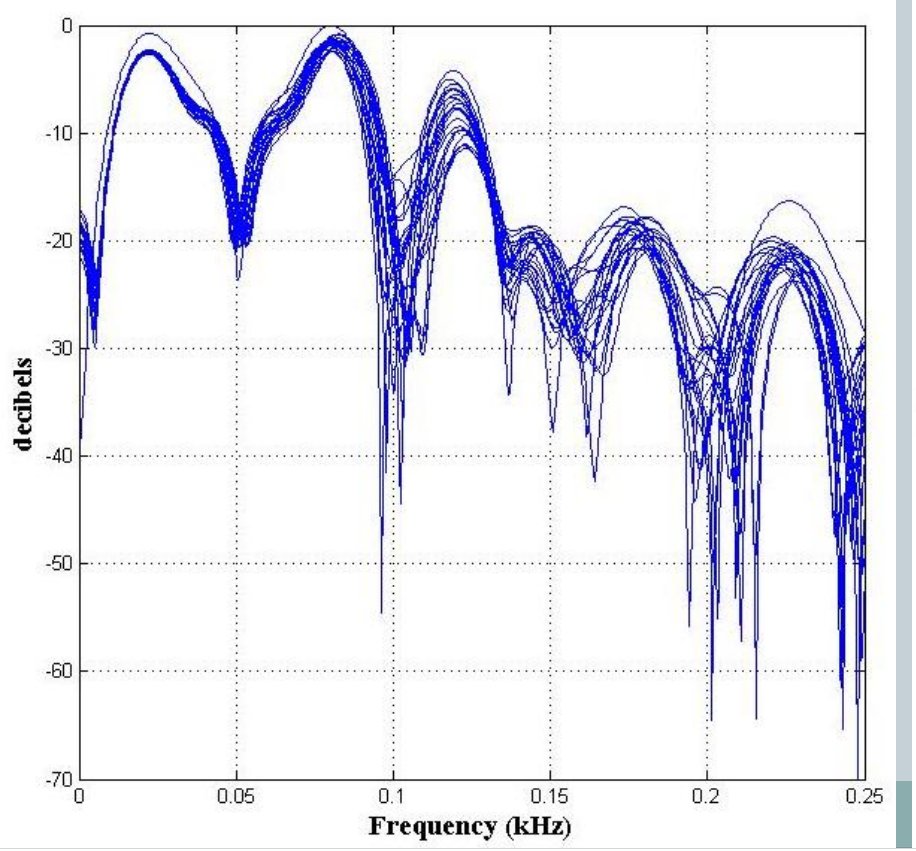
Efek ghost notch sudah tereliminasi oleh proses deghosting.

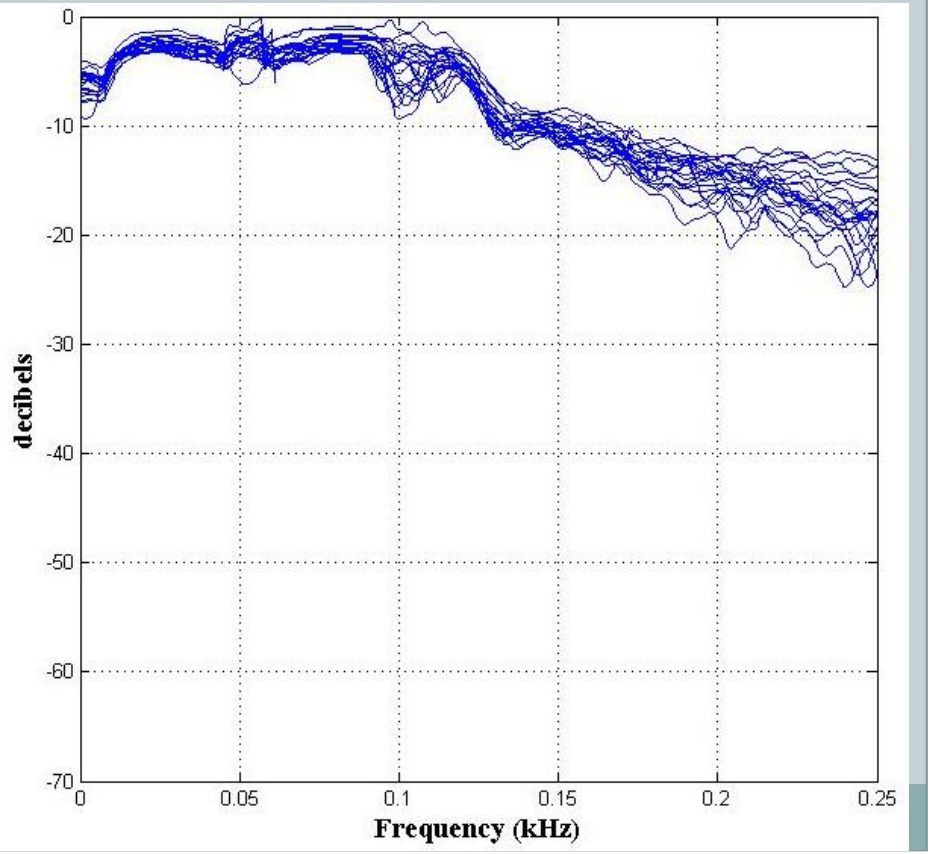




Hasil Deghosting: Spektrum Frekuensi Data Sintetik

Spektrum Frekuensi data sintetik (kiri)combined mode dan (kanan)combine mode dengan deghosting

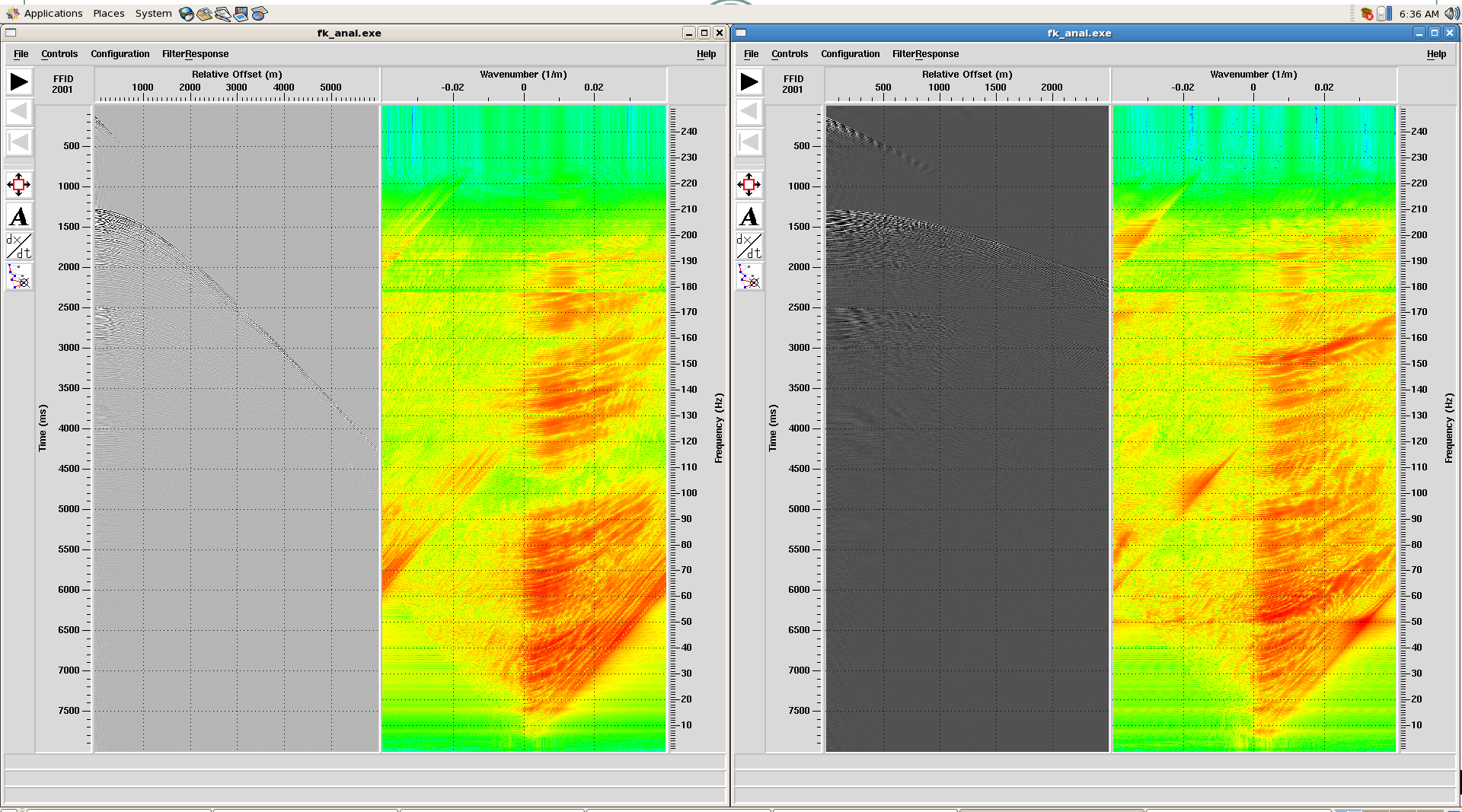




Analisa Hasil Pengolahan Data Sintetik

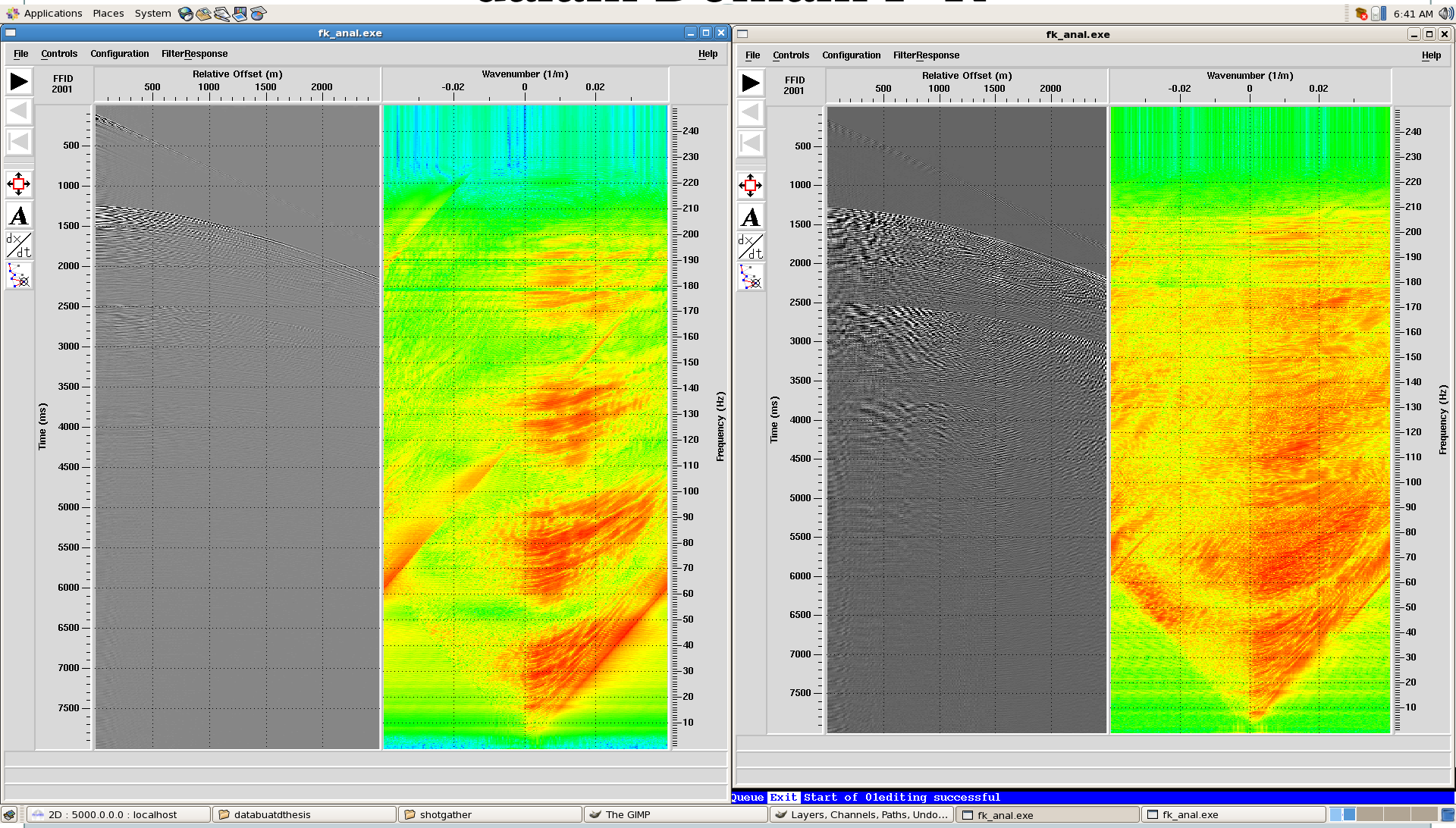
- Deghosting berhasil dilakukan pada sintetik, dengan menggunakan total operator ghost, untuk menghilangkan semua komponen ghost.
- Teknik combined mode yang menjumlahkan data dari tiga streamer, kurang berhasil karena konfigurasi yang digunakan tidak tepat .
- Apabila hanya ingin menerapkan combine mode saja tempatkan sumber pada kedalaman 7.5meter.
- Berhubung pada penelitian ini targetnya adalah target dalam maka kedalaman sumber pada kedalaman 15 meter efektif untuk menghindari surface noise. Sehingga pada teknik combined mode perlu ditambahkan teknik deghosting pada masing-masing streamer.

Hasil Deghosting data lapangan dalam domain F-K

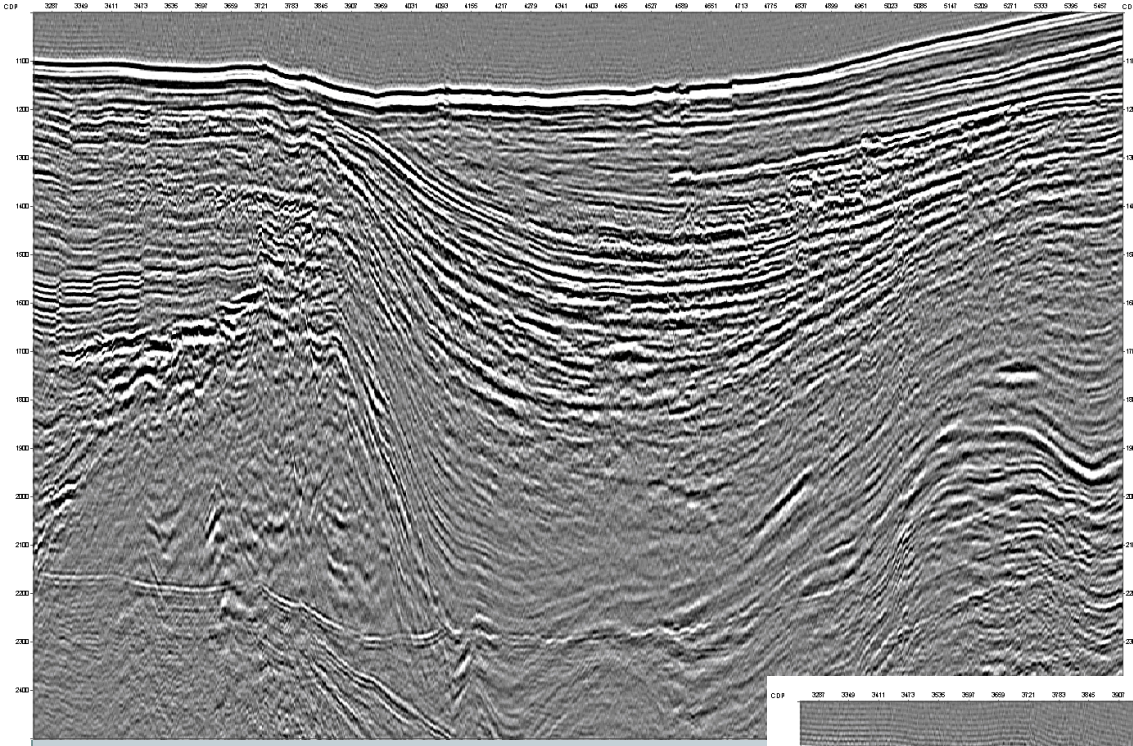


Shot gather dalam F-K domain, (kiri)sebelum deghosting, (kanan) setelah deghosting kedalaman streamer 7.5

Hasil Deghosting data lapangan dalam Domain F-K



Shot gather dalam F-K domain, (kiri)sebelum deghosting, (kanan) setelah deghosting kedalaman streamer 15

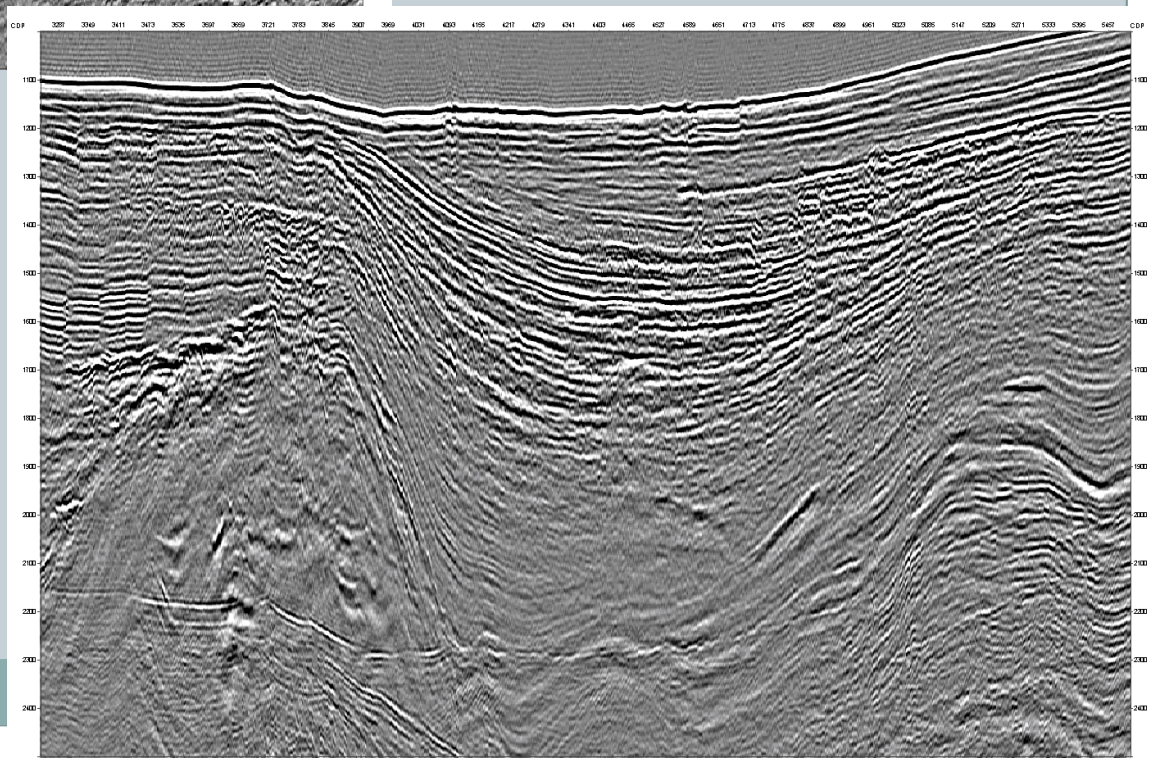


Hasil Pengolahan Penampang Seismik Kedalaman Streamer 7.5 meter

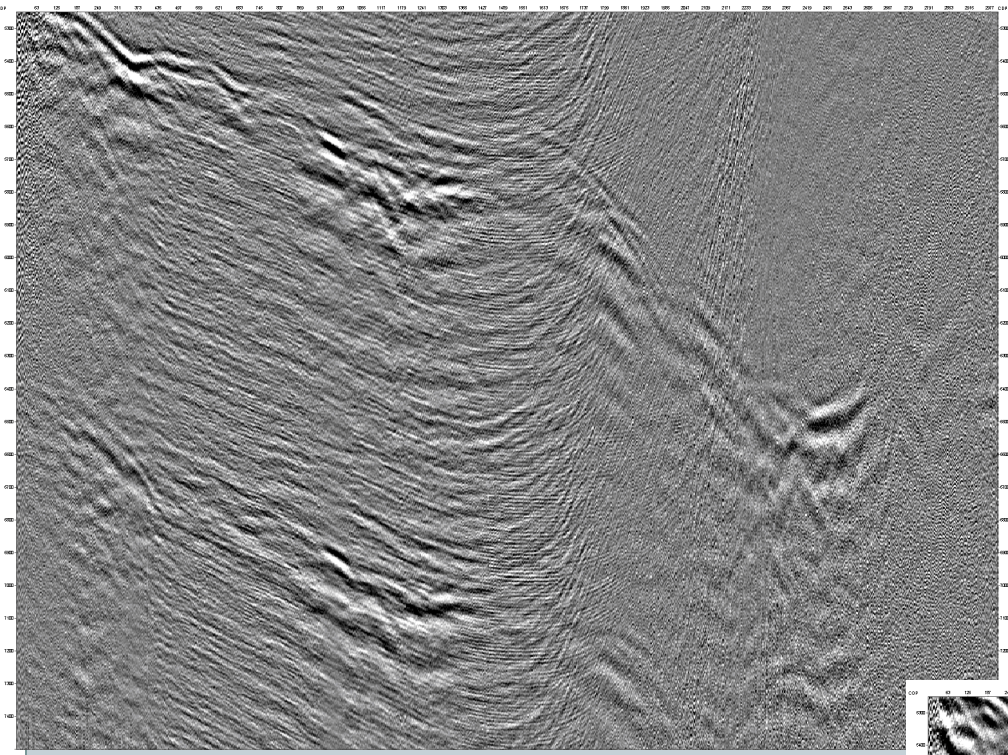
Untuk Target Dangkal: permukaan dasar laut-2.5 s

(atas) Penampang Seismik sebelum deghosting.

(bawah) Penampang Seismik setelah deghosting.



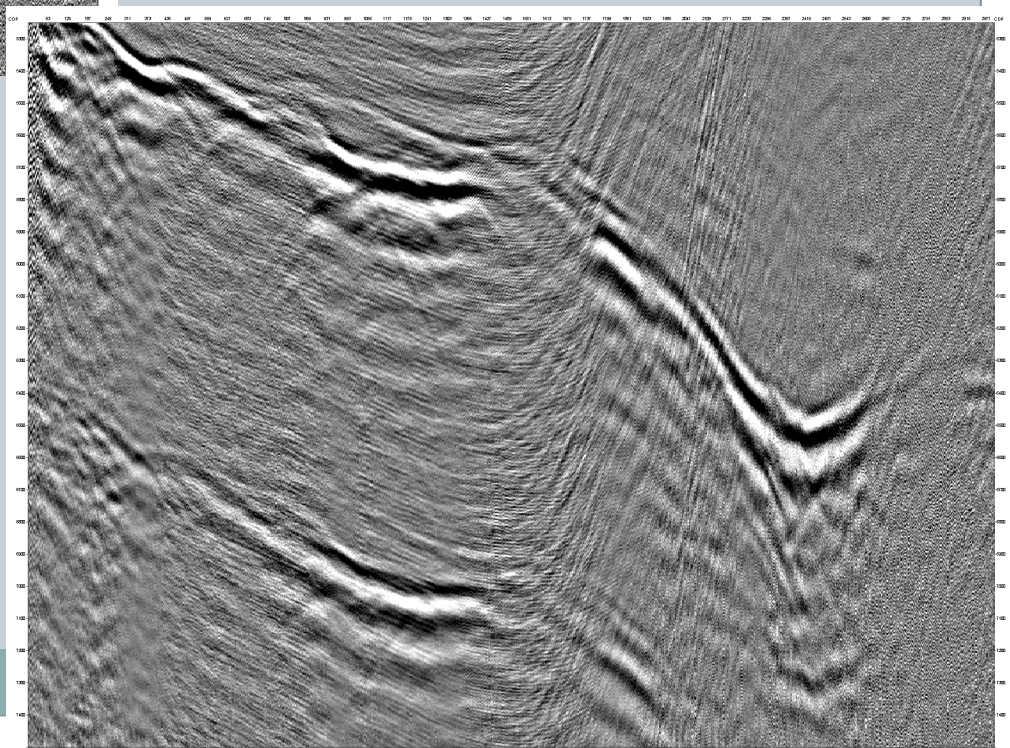
Hasil Pengolahan Penampang Seismik Kedalaman Streamer 7.5 meter



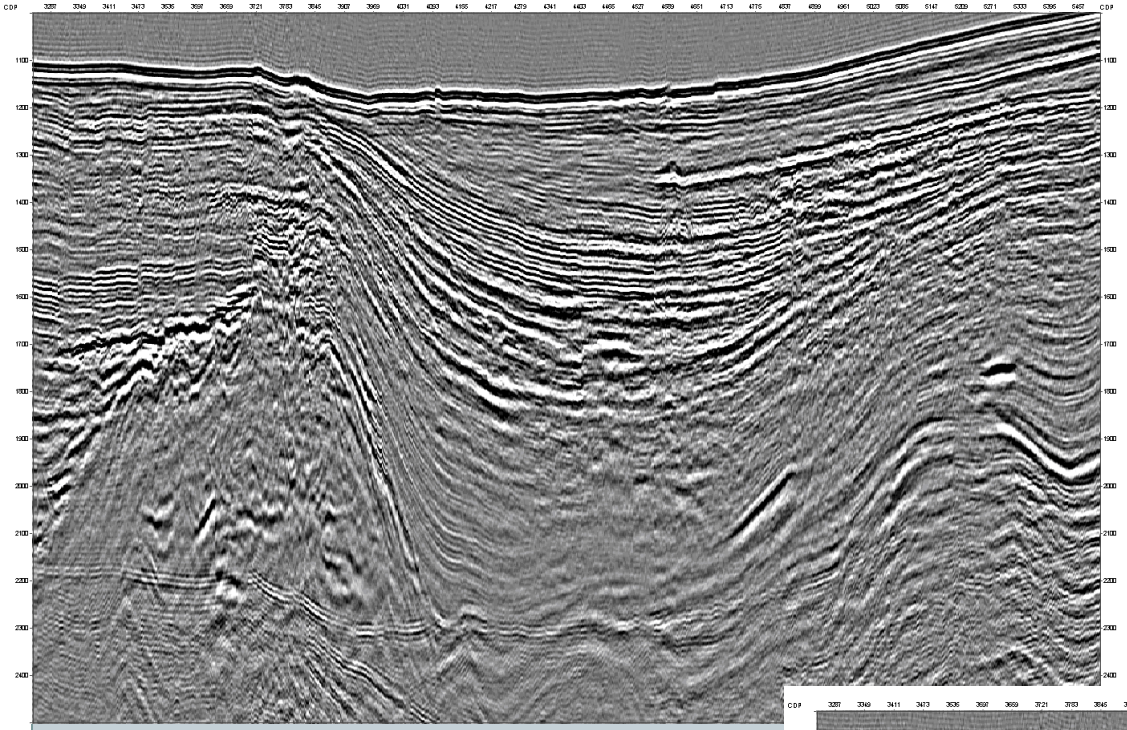
Untuk Target Dalam:
5.25 – 7.5 s

(atas) Penampang Seismik sebelum deghosting.

(bawah) Penampang Seismik setelah deghosting.



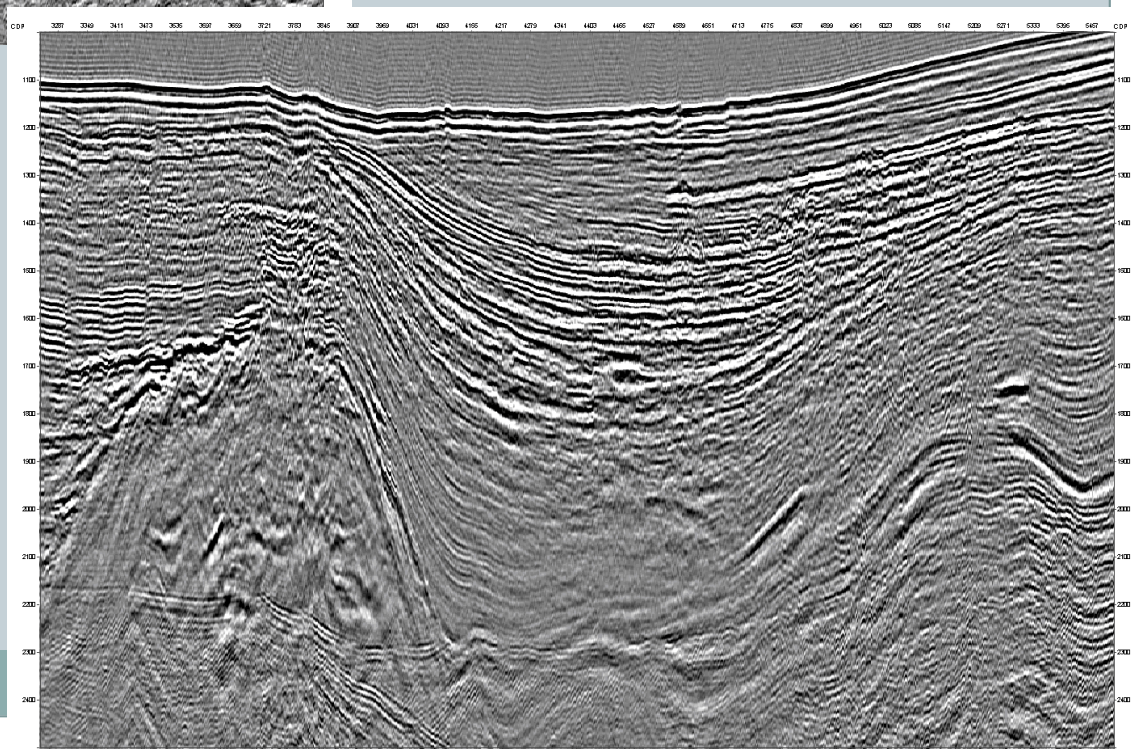
Hasil Pengolahan Penampang Seismik Kedalaman Streamer 15 meter

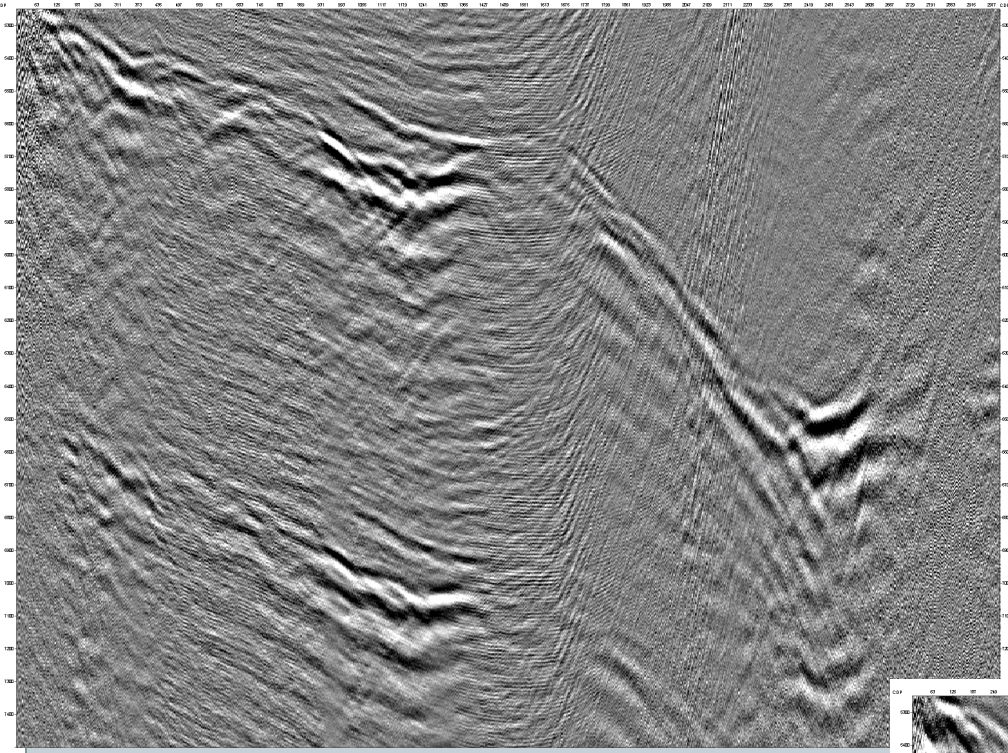


Untuk Target Dangkal: permukaan dasar laut-2.5 s

(atas) Penampang Seismik sebelum deghosting.

(bawah) Penampang Seismik setelah deghosting.



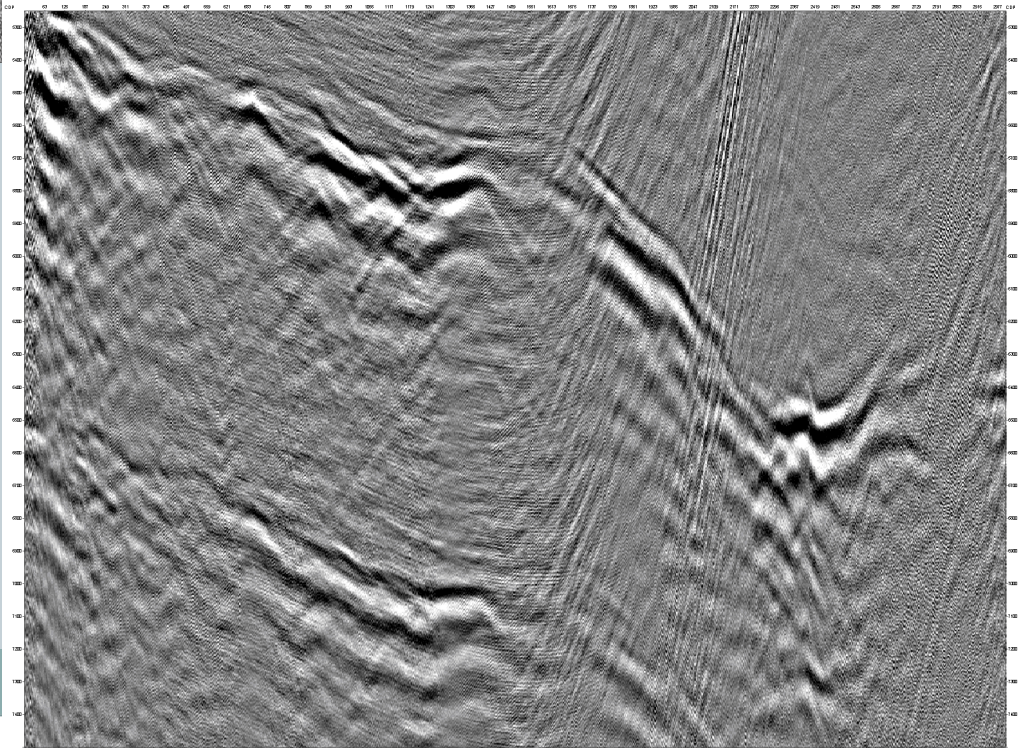


Hasil Pengolahan Penampang Seismik Kedalaman Streamer 15 meter

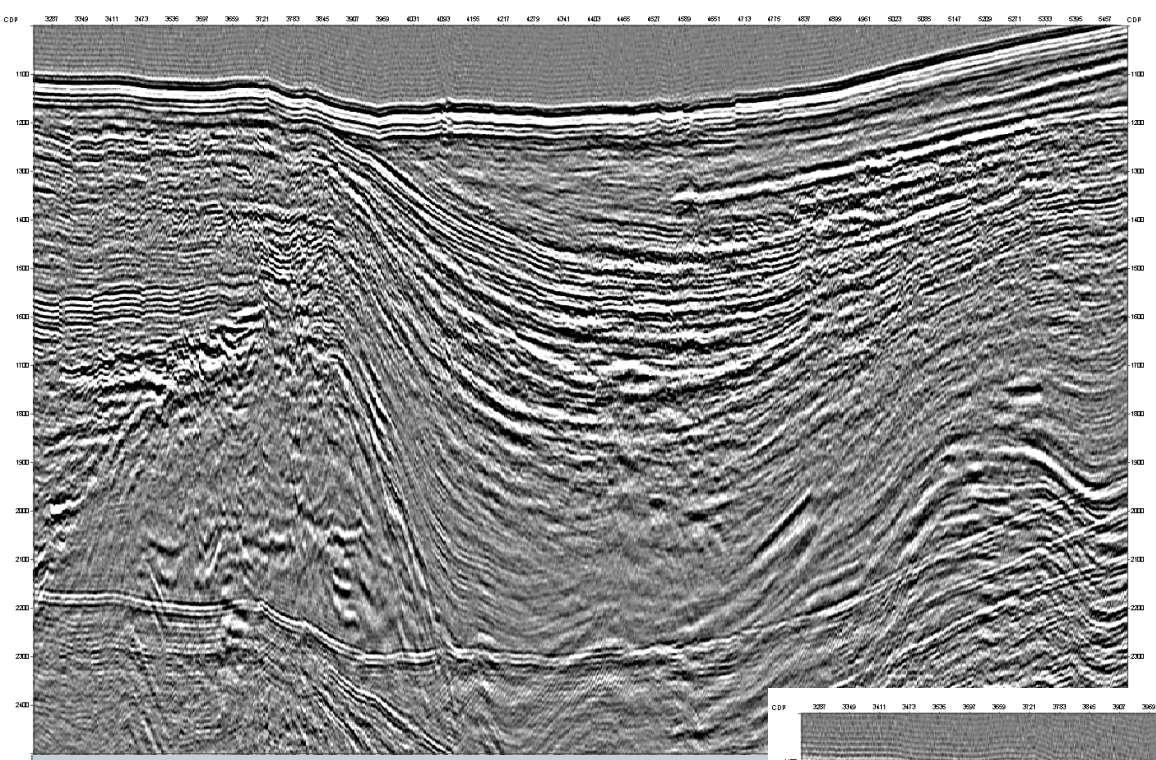
Untuk Target Dalam:
5.25 – 7.5 s

(atas) Penampang Seismik sebelum deghosting.

(bawah) Penampang Seismik setelah deghosting.



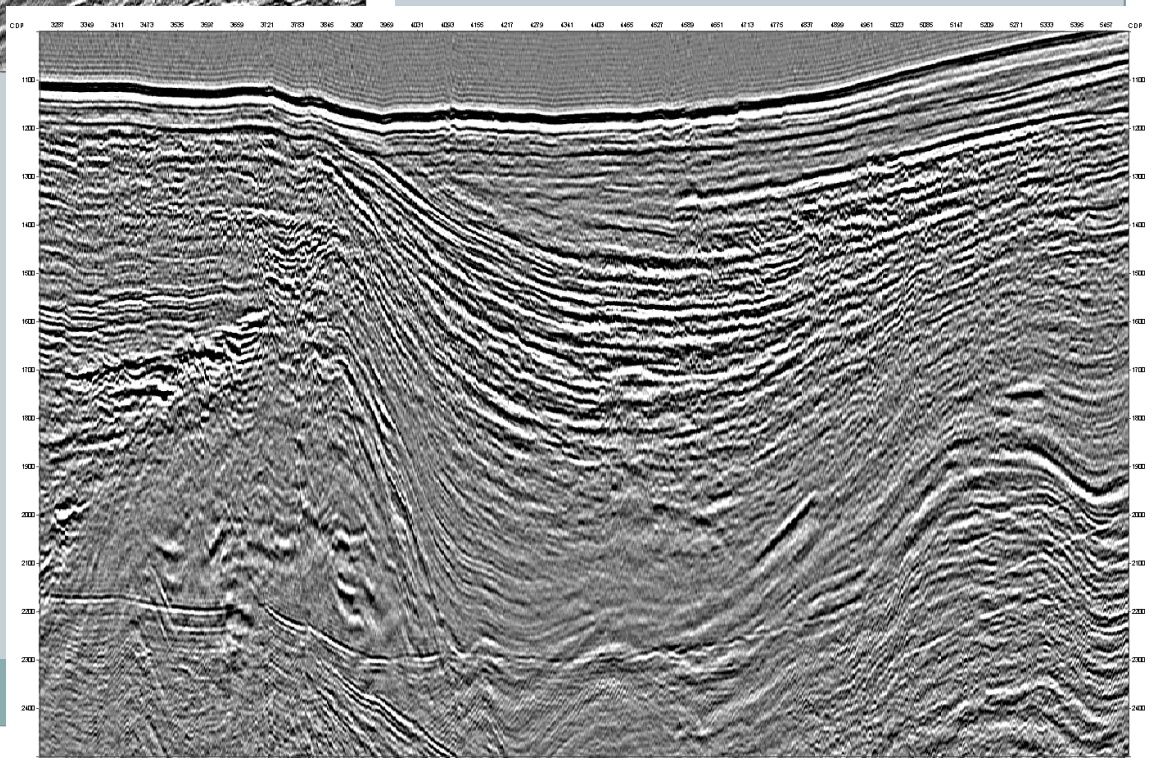
Hasil Pengolahan Penampang Seismik



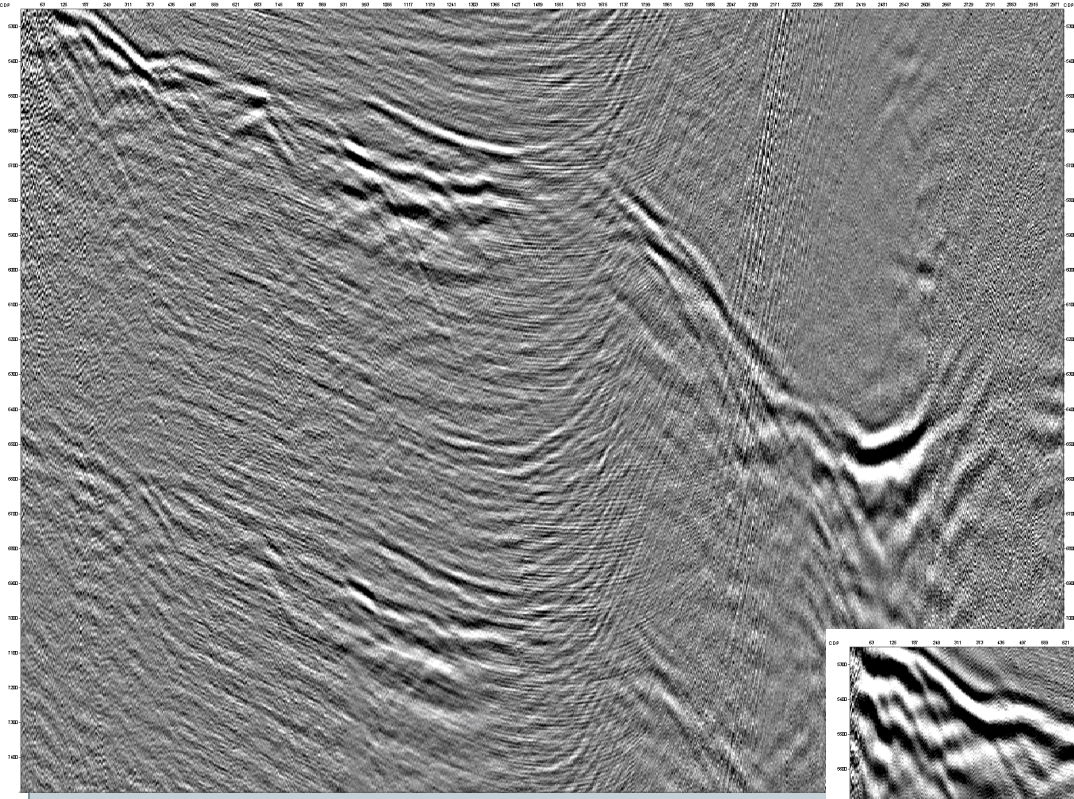
Untuk Target Dangkal: permukaan dasar laut-2.5 s

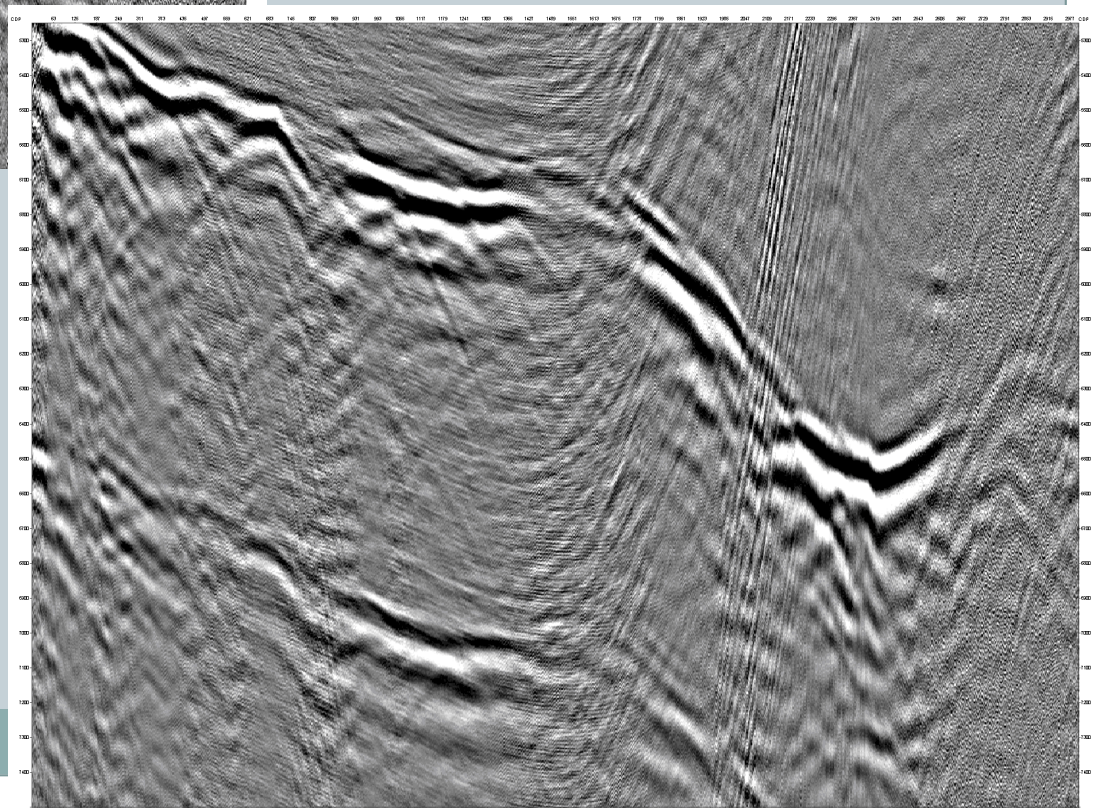
(atas) Penampang Seismik combined mode tanpa deghosting.

(bawah) Penampang Seismik combined mode dengan deghosting.



Hasil Pengolahan Penampang Seismik



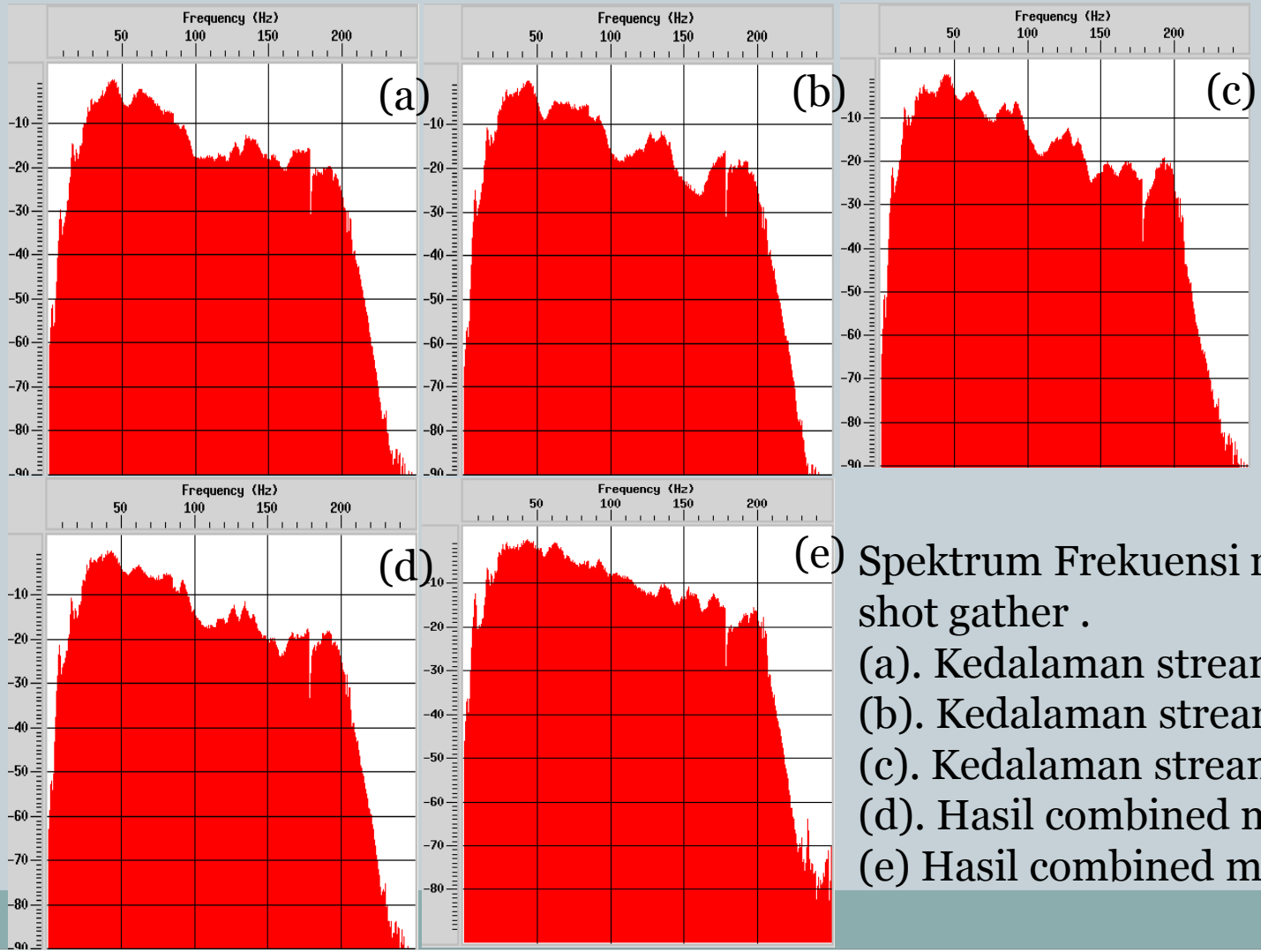


Untuk Target Dalam:
5.25 – 7.5 s

(atas) Penampang Seismik combined mode tanpa deghosting.

(bawah) Penampang Seismik combined mode dengan deghosting.

Spektrum Frekuensi Hasil Akhir Pengolahan



Spektrum Frekuensi respon dari suatu shot gather .

(a). Kedalaman streamer 7.5

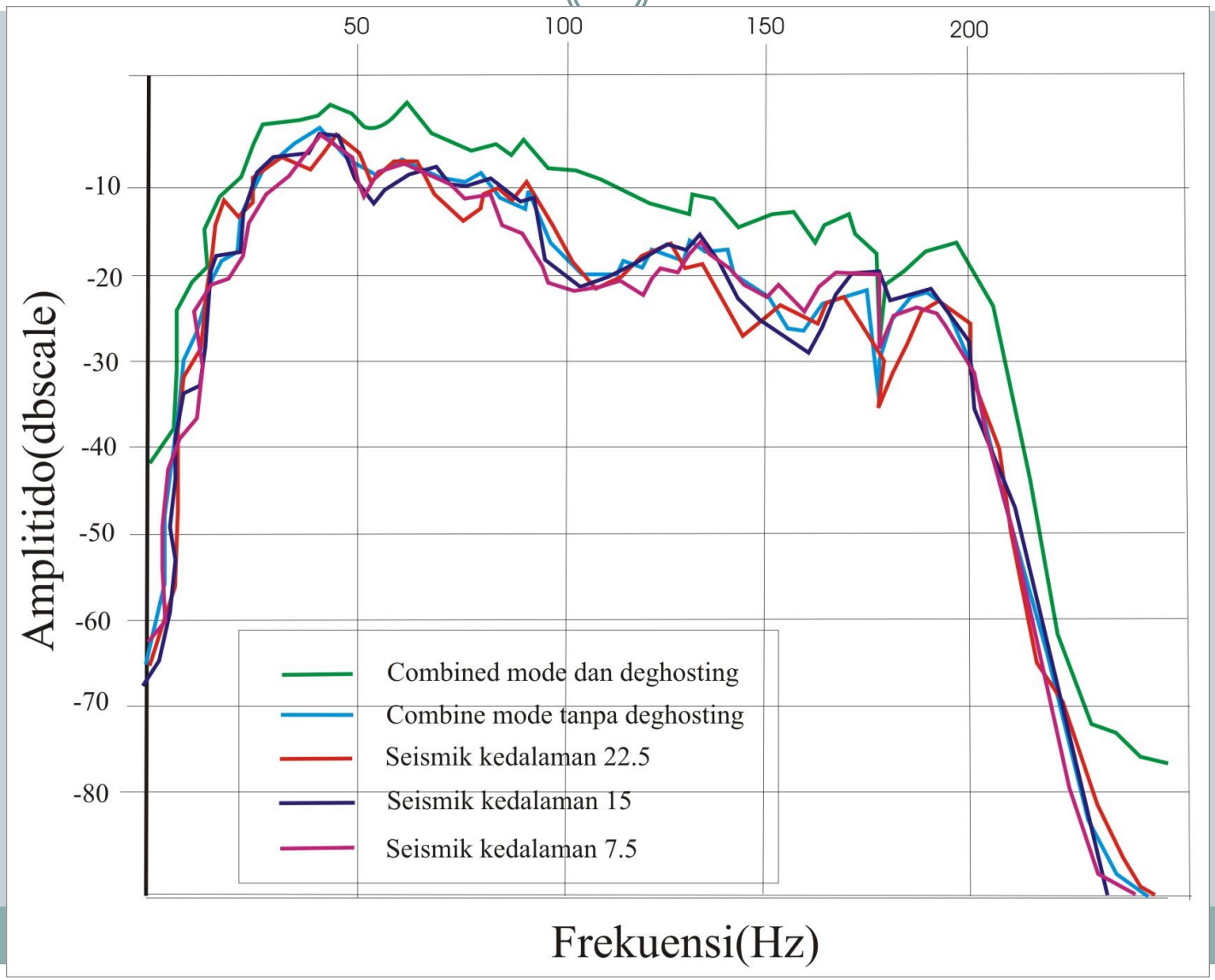
(b). Kedalaman streamer 15

(c). Kedalaman streamer 22.5

(d). Hasil combined mode

(e) Hasil combined mode + deghosting

Spektrum Frekuensi Hasil Akhir Pengolahan



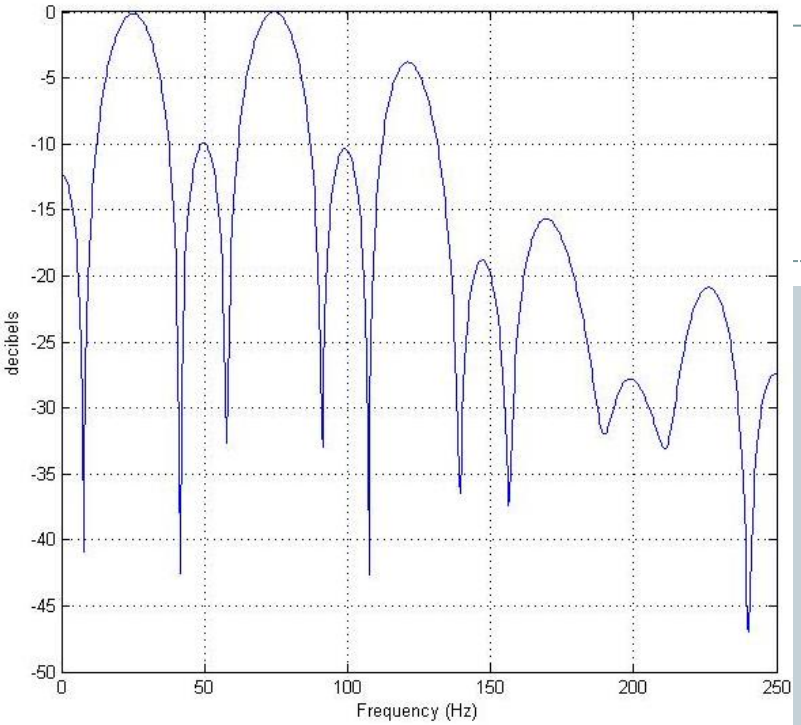
Analisis Hasil Pengolahan Data

- Hasil pengolahan combined mode dengan deghosting lebih optimal dalam mereduksi ghost atau ghost notch pada spektrum frekuensi.
- Konfigurasi over-under yang dilakukan di data ini tidak optimal untuk menggantikan deghosting, karena penempatan kedalaman sumber 15 meter. Konfigurasi over-under akan optimal sebagai teknik deghosting apabila kedalaman sumber ditempatkan pada kedalaman 7.5 meter.

Kesimpulan

- Teknik akuisisi over-under streamer terhadap data lapangan dengan menggunakan combine mode secara langsung, belum menghasilkan data broadband seismik. Sangat terlihat jelas pada data sintetik
- Aplikasi pengolahan combined mode dengan deghosting merupakan teknik pengolahan data broadband seismik untuk konfigurasi data ini.
- Dengan konfigurasi over-under target dalam tercapai, image seismik lebih baik, tanpa mengurangi resolusi untuk target dangkal.

Terima Kasih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Frequency (Hz)
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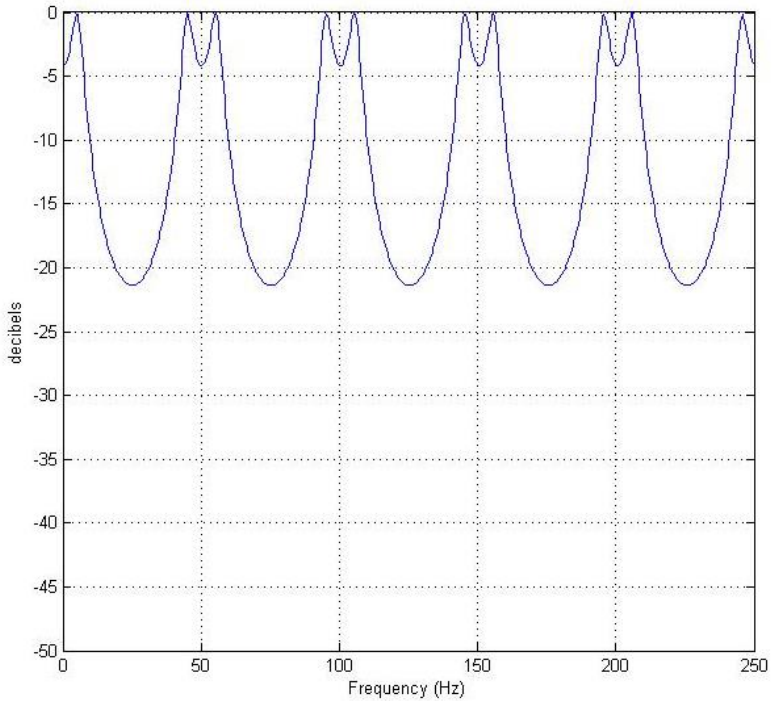
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
0
50
100
150
200
250


decibels
Frequency (Hz)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
0
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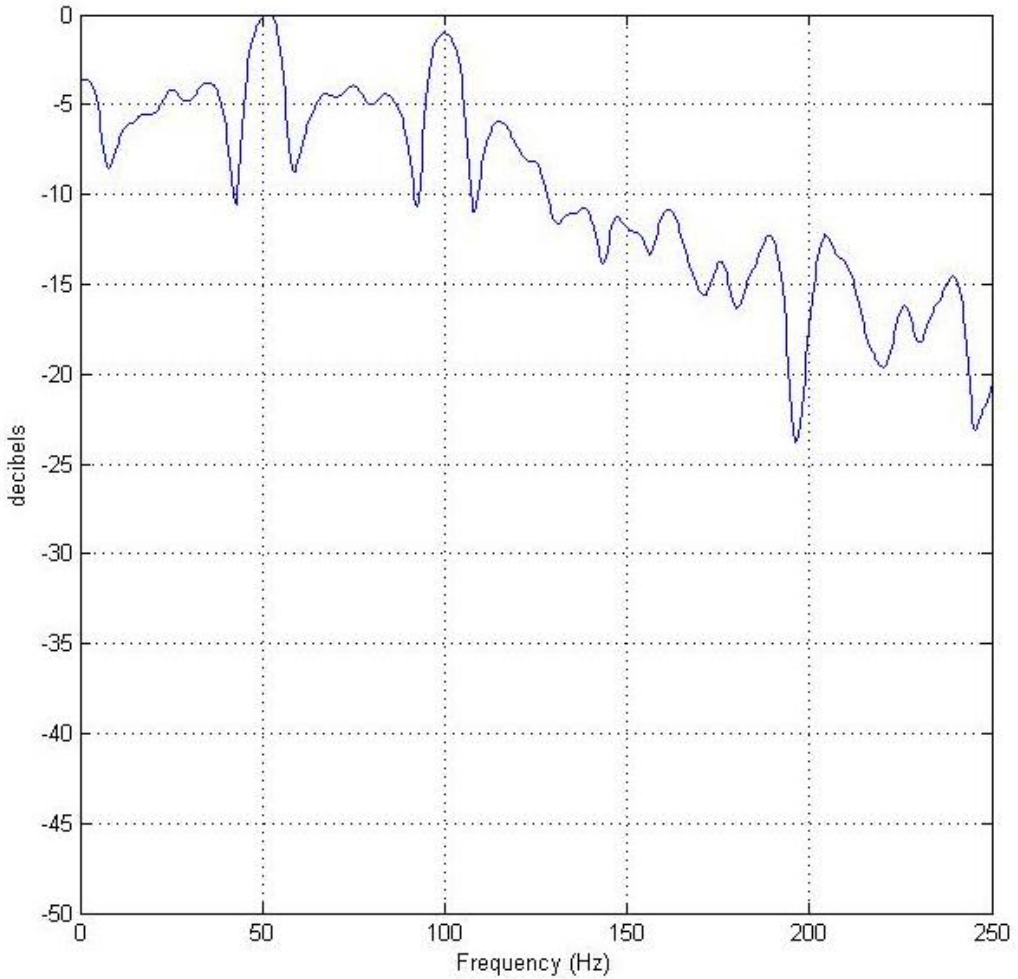
100
150
200
250


decibels
Frequency (Hz)
0
-5
-10
-15
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-30
-35
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-45
-50
0
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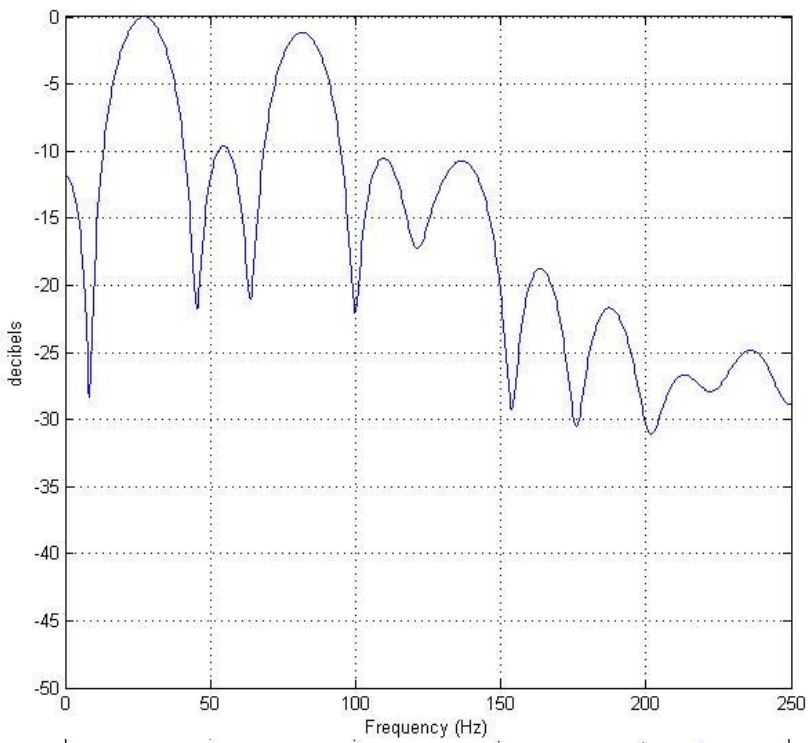
0
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-20
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-40
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decibels
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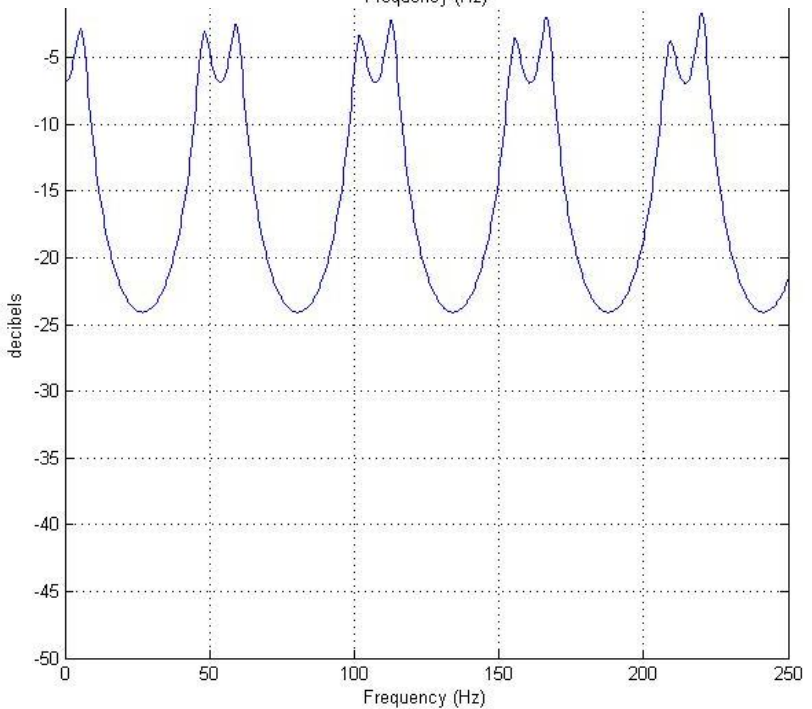
Frequency (Hz)


-5
-10
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-20
-25
-30
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-40
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-50
decibels
0
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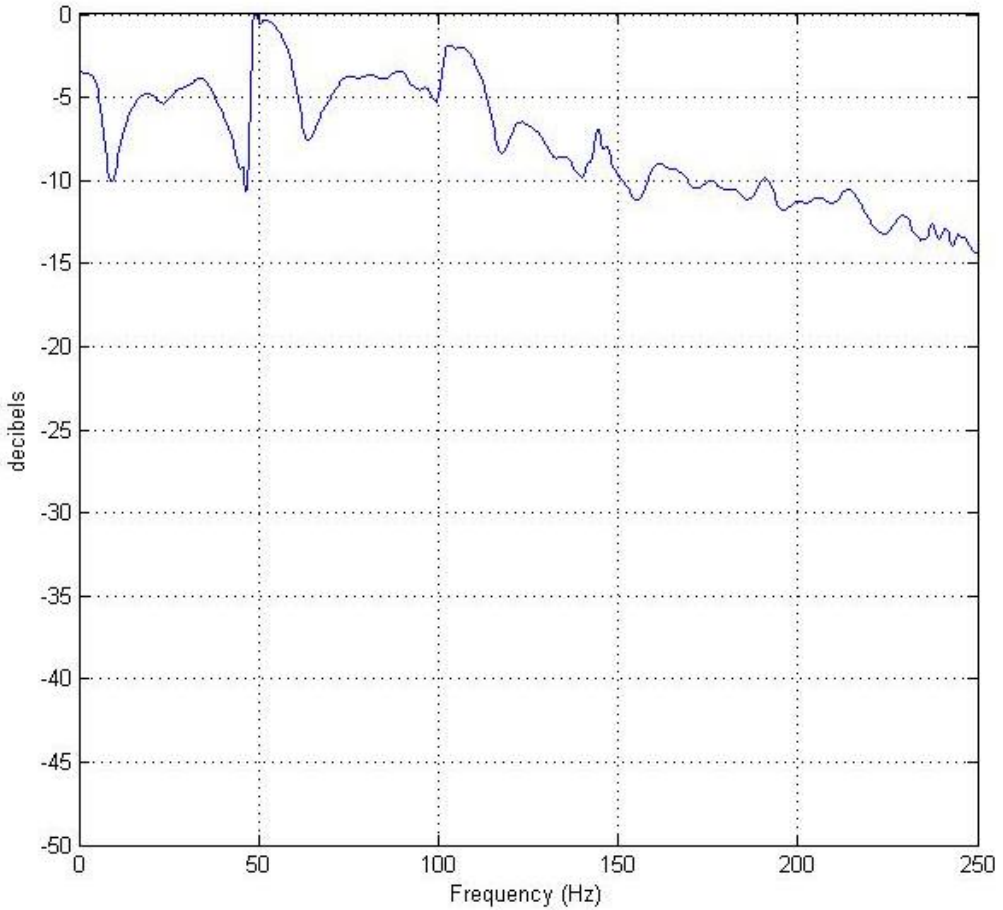
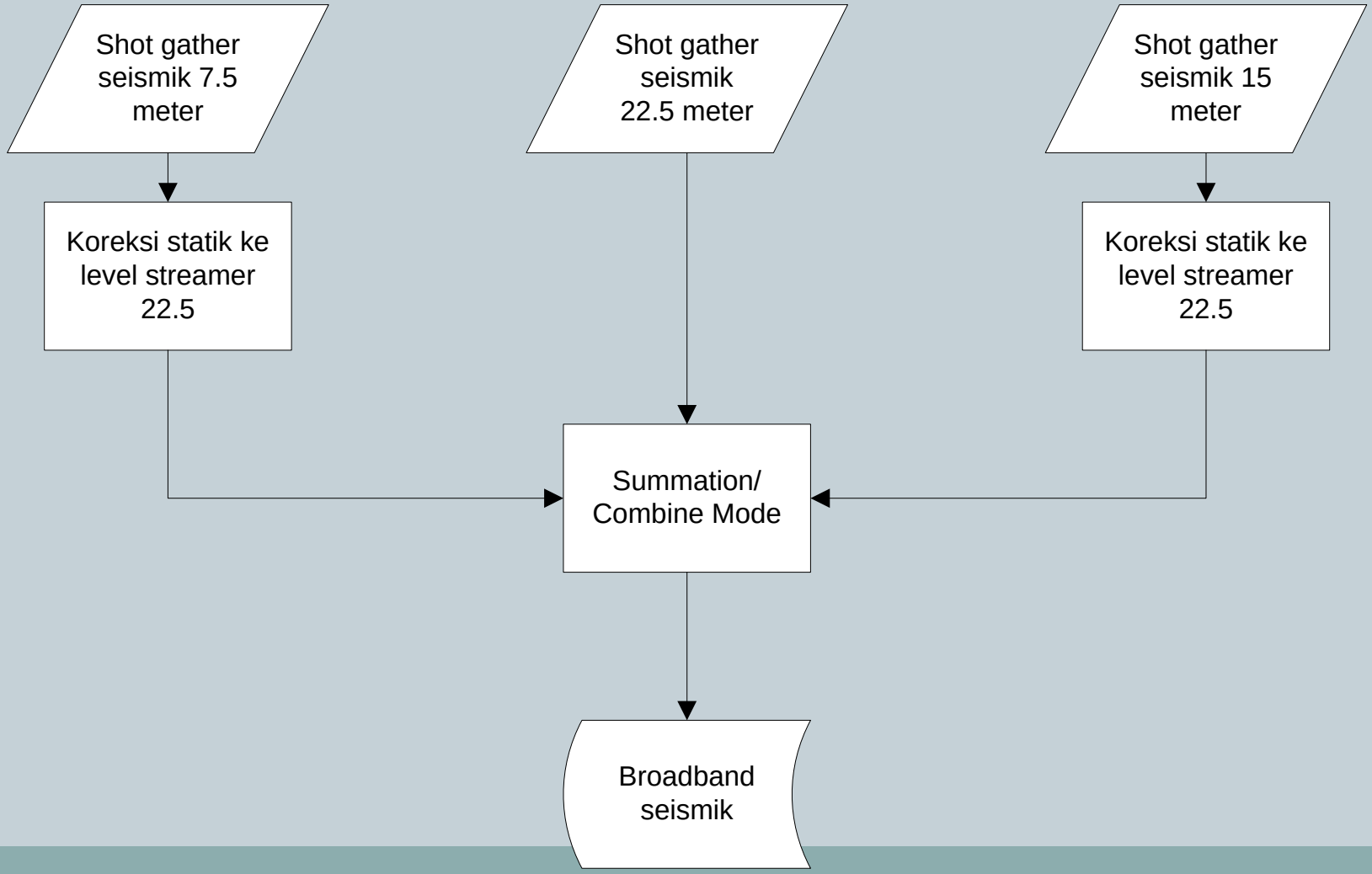
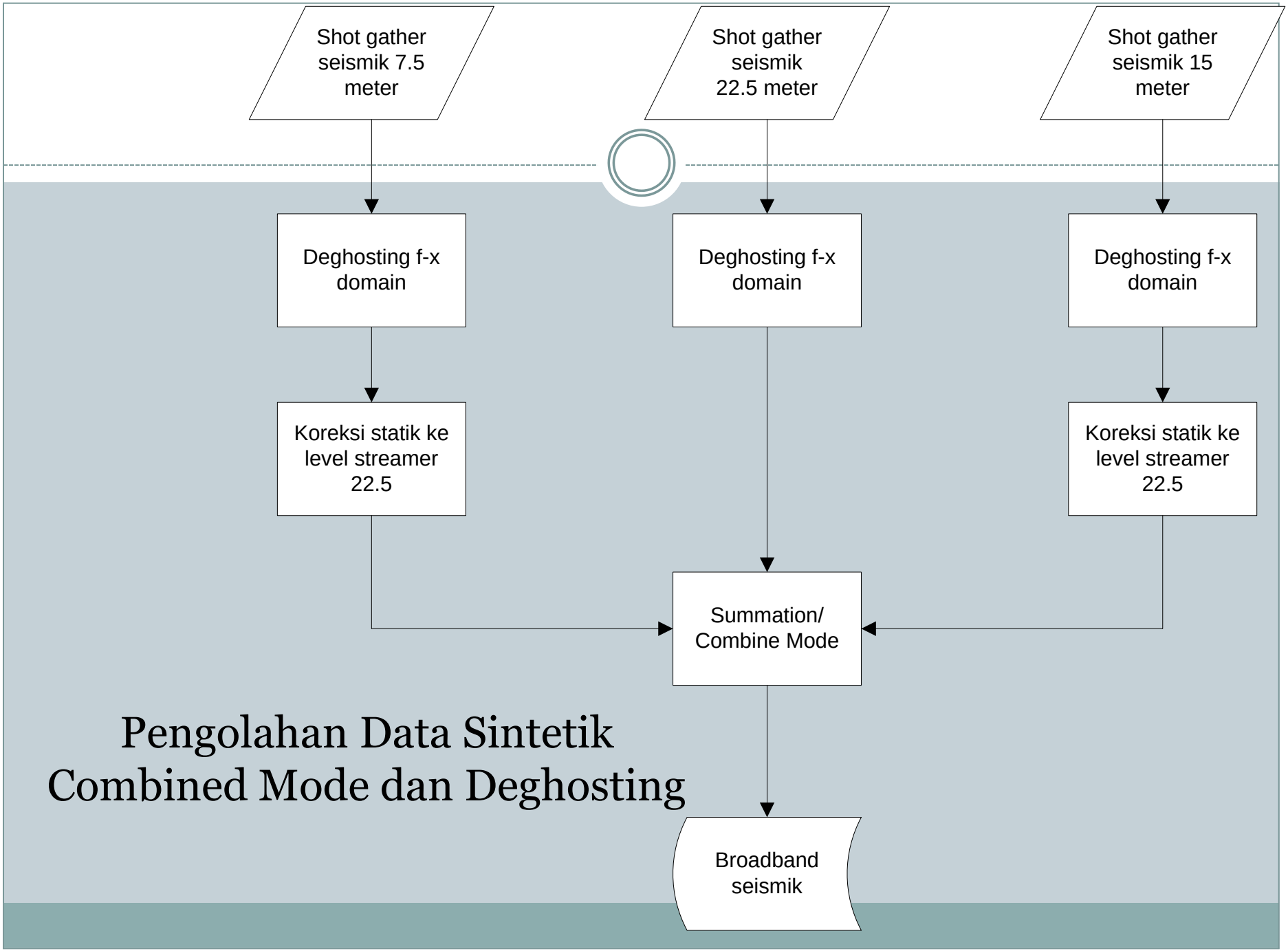
250
Frequency (Hz)


0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
decibels
0
50
100
150
200
250
Frequency (Hz)

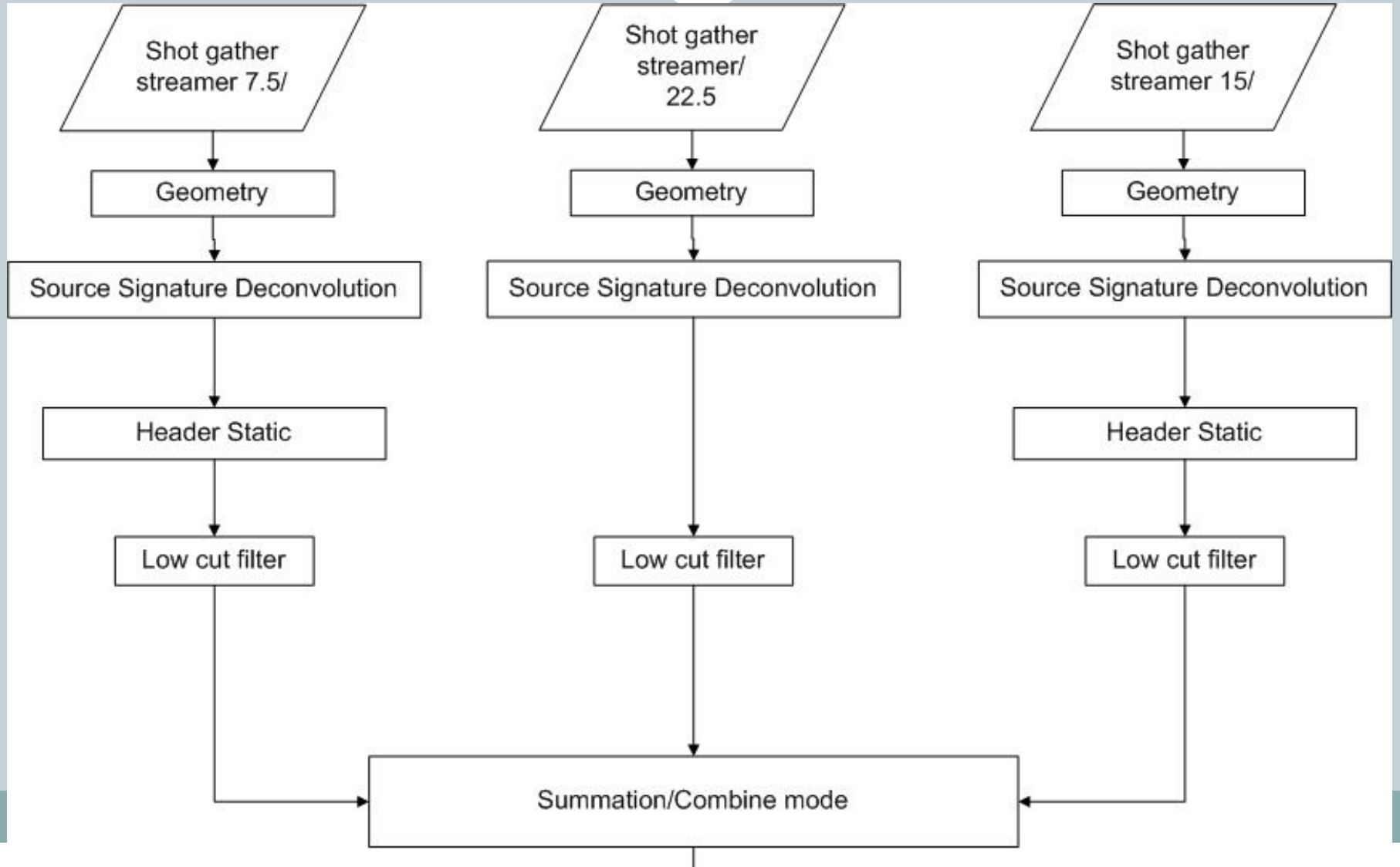
Pengolahan Data Sintetik Combined Mode



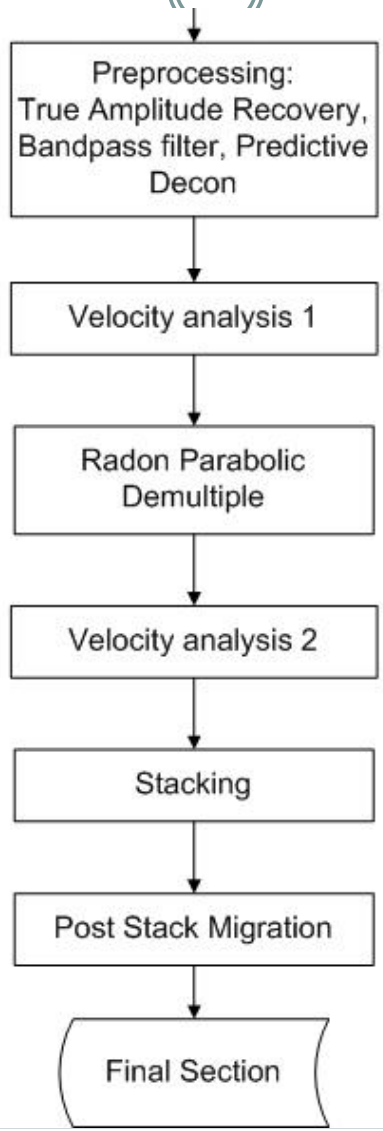


Pengolahan Data Sintetik Combined Mode dan Deghosting

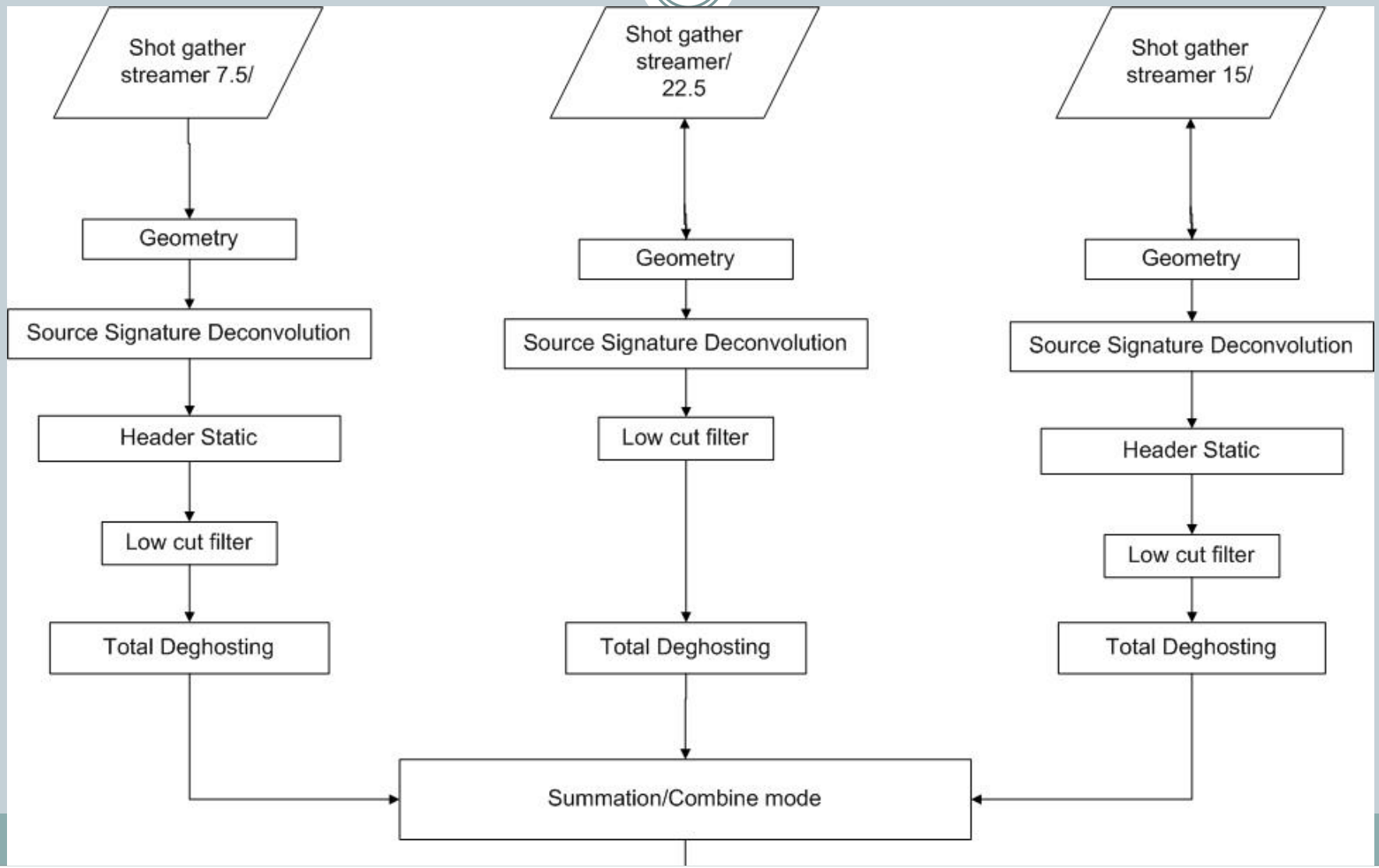
Pengolahan Data Lapangan Combined Mode



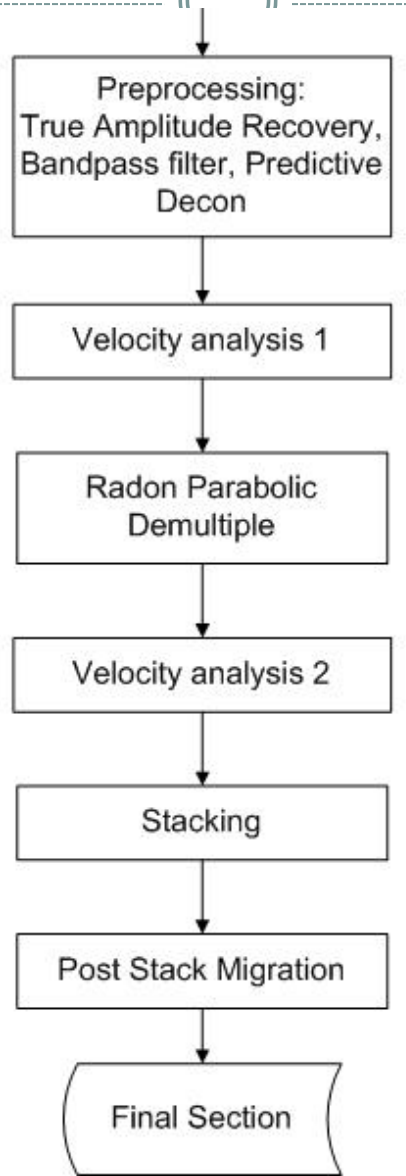
Pengolahan Data Lapangan Combined Mode



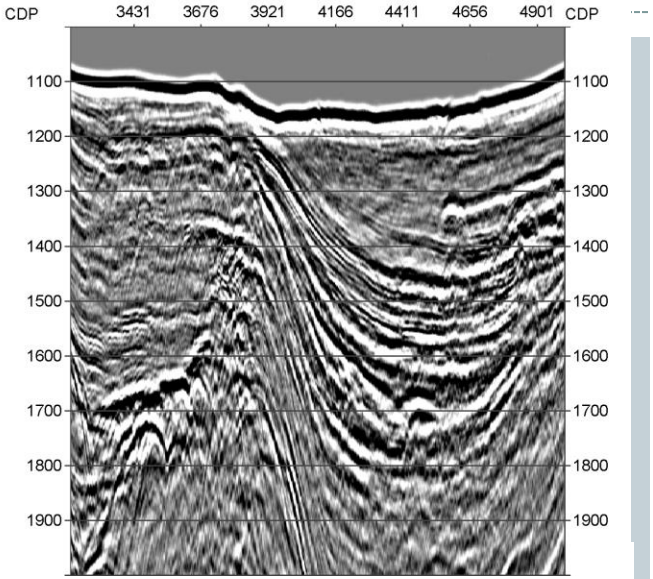
Pengolahan Data Lapangan Combined Mode dan Deghosting

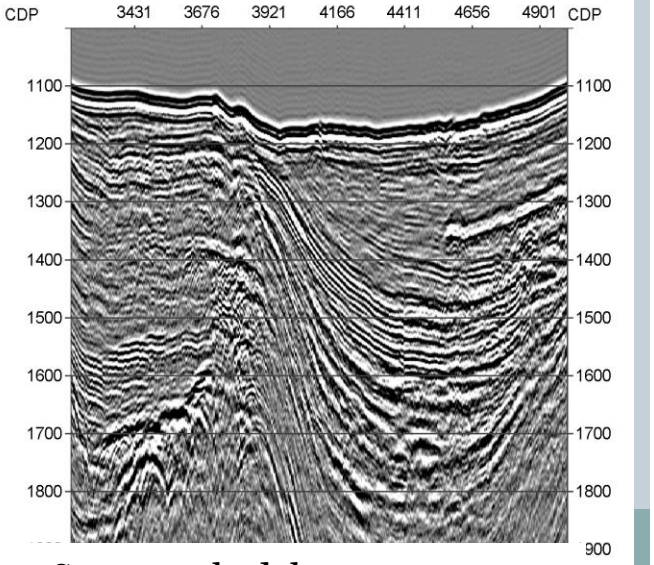


Pengolahan Data Lapangan Combined Mode dan Deghosting

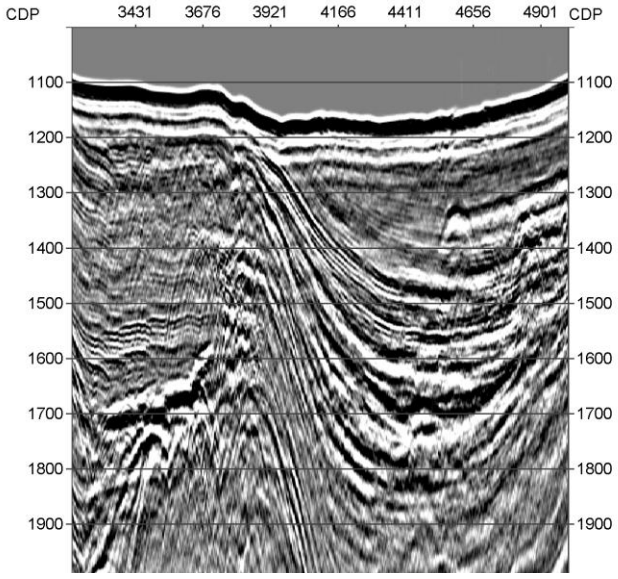


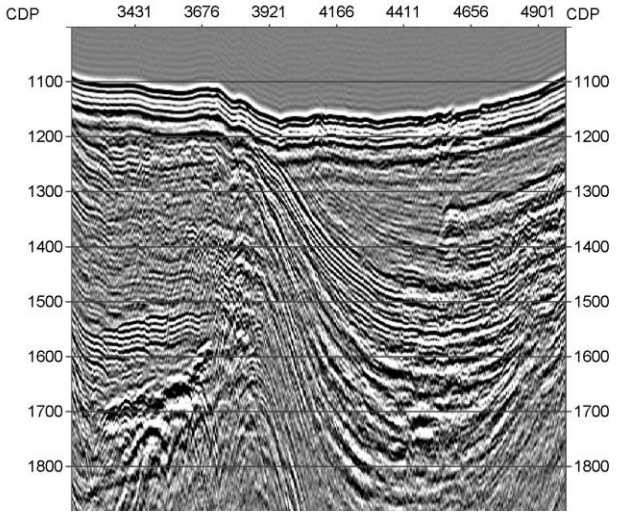
Efek Source Signature Deconvolution Pada Data Lapangan



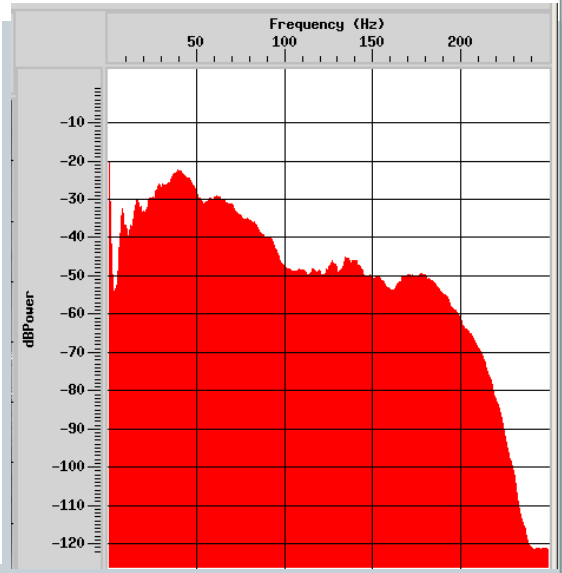


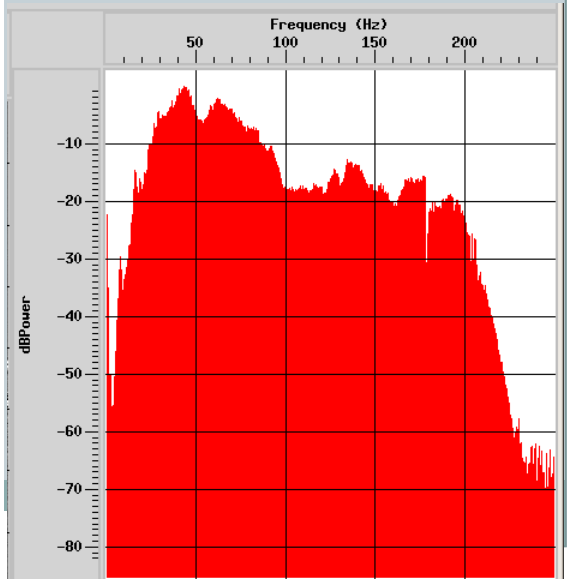
Streamer kedalaman 15 meter





Streamer kedalaman 22.5 meter



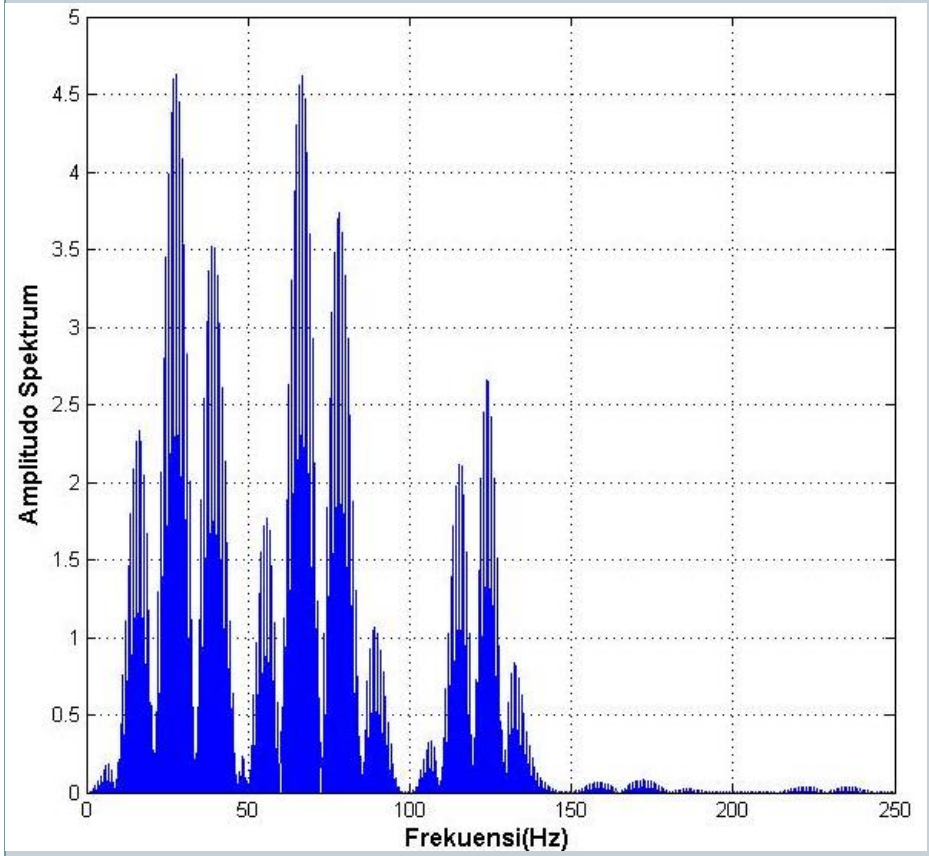


DEFINITIONS by SEG

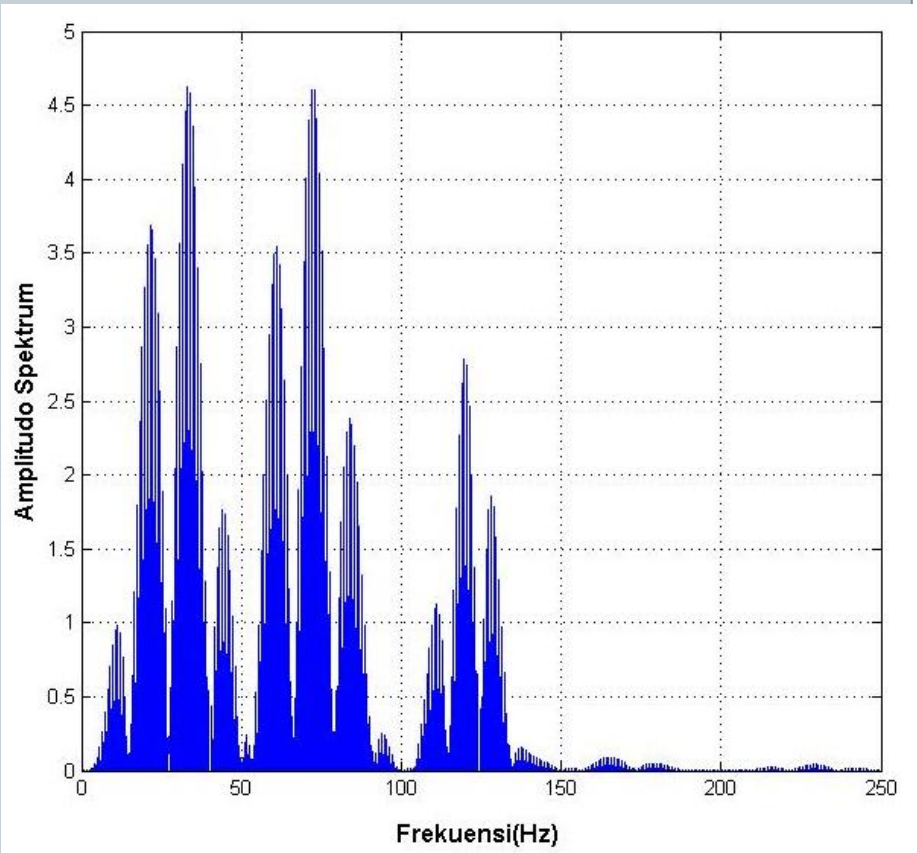
Near-field signature
A near-field signature is an acoustic wavelet whose direct arrival from the marine source is very large (>20 dB) compared with reflections from adjacent boundaries or interfaces. Near-field signatures are usually recorded for a single source or a point source. A point source is one whose dimensions are small compared with the shortest wavelength of interest, $L \ll \lambda$.

Far-field signature
A far-field signature is characterized by a direct wavelet plus its reflection (ghost) from the air-water interface. The ratio of the direct-to-ghost travel distances should approach 1.0. Far-field signatures are usually recorded for an array of sources (a directional source). A directional source is one whose dimensions are of the same order as the wavelengths of interest, $L \approx \lambda$.

Spektrum Data Sintetik, Real dan Imaginer

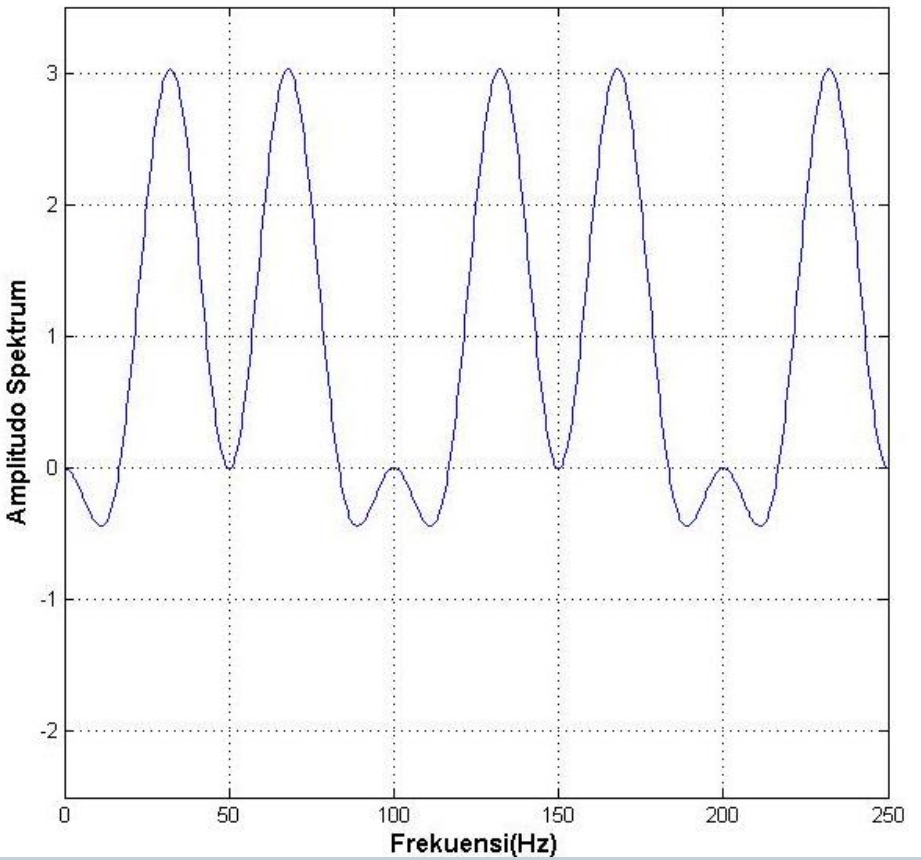


Spektrum Data Sintetik (Real)

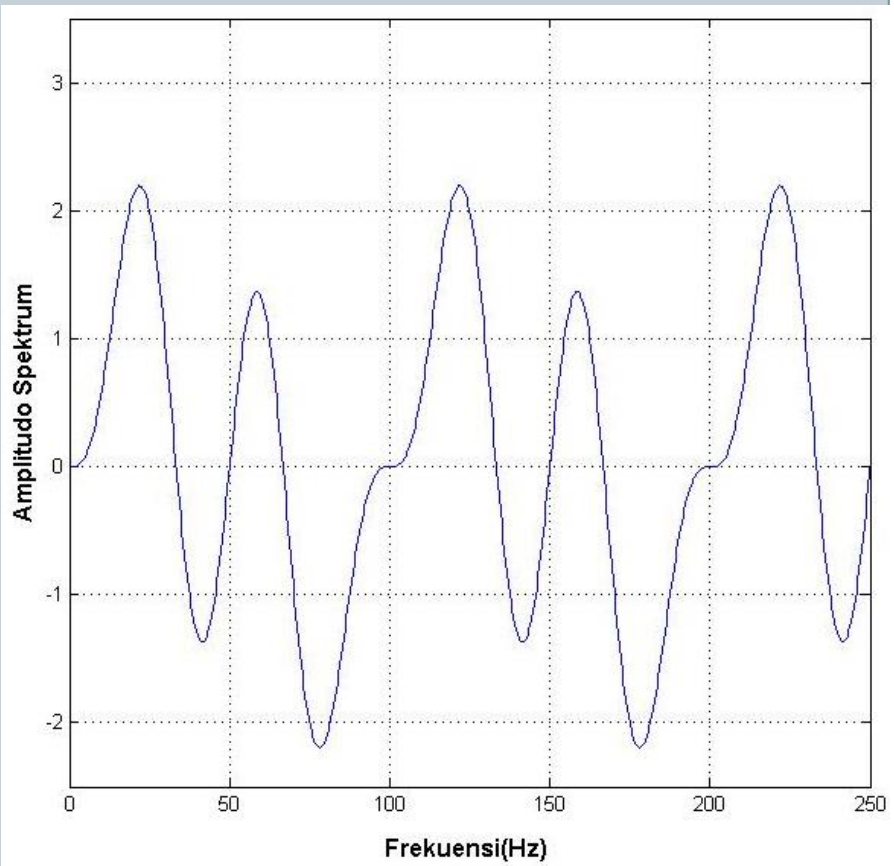


Spektrum Data Sintetik (Imaginer)

Spektrum Total Operator Ghost :Real dan Imaginer, Data Kedalaman Streamer 7.5 meter

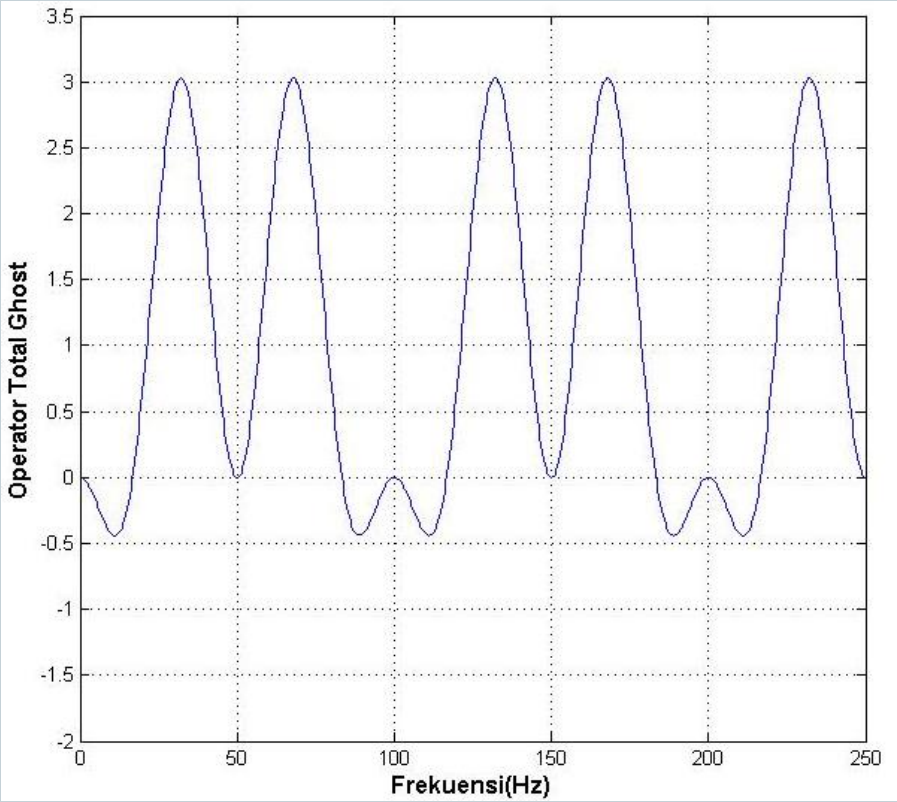


Spektrum Operator Ghost(Real)

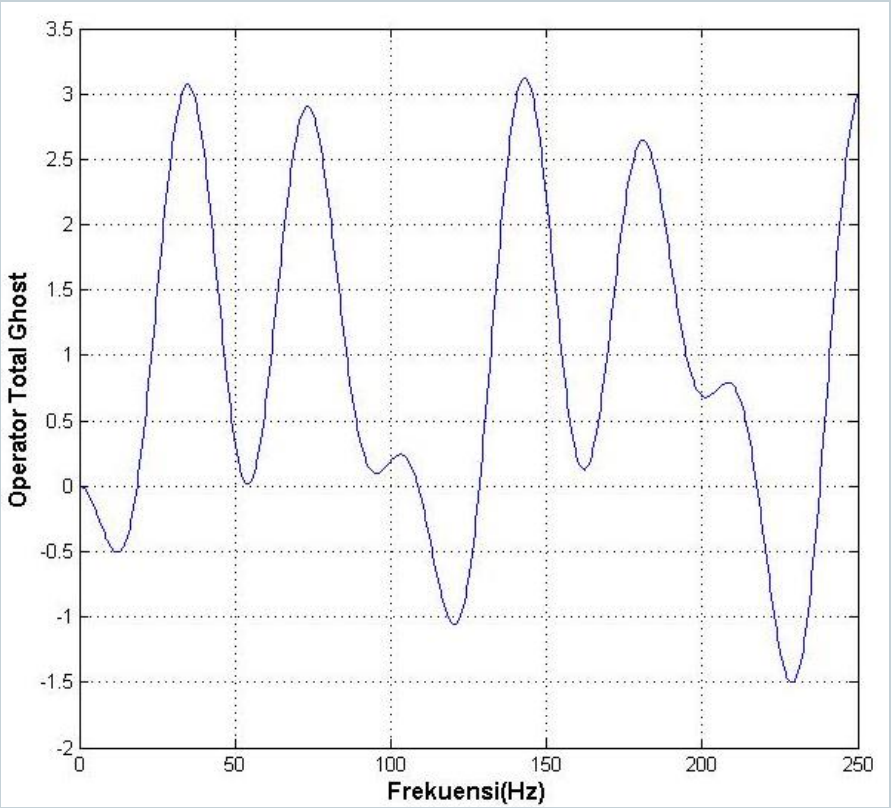


Spektrum Operator Ghost (Imaginer)

Operator Total Ghost Kedalaman Streamer 7.5 meter

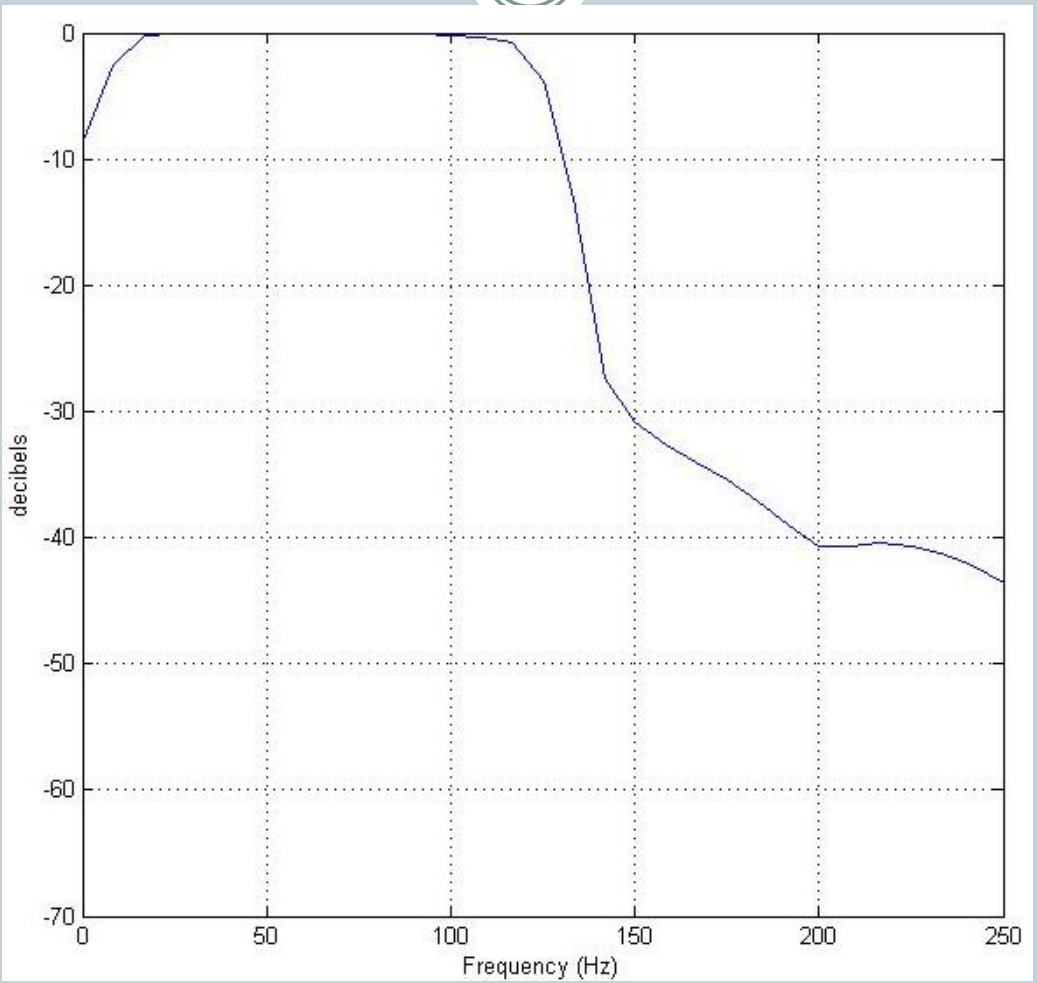


Operator Total Ghost Near Trace(Channel 1)



Operator Total Ghost far Trace(Channel 48)

Spektrum Wavelet



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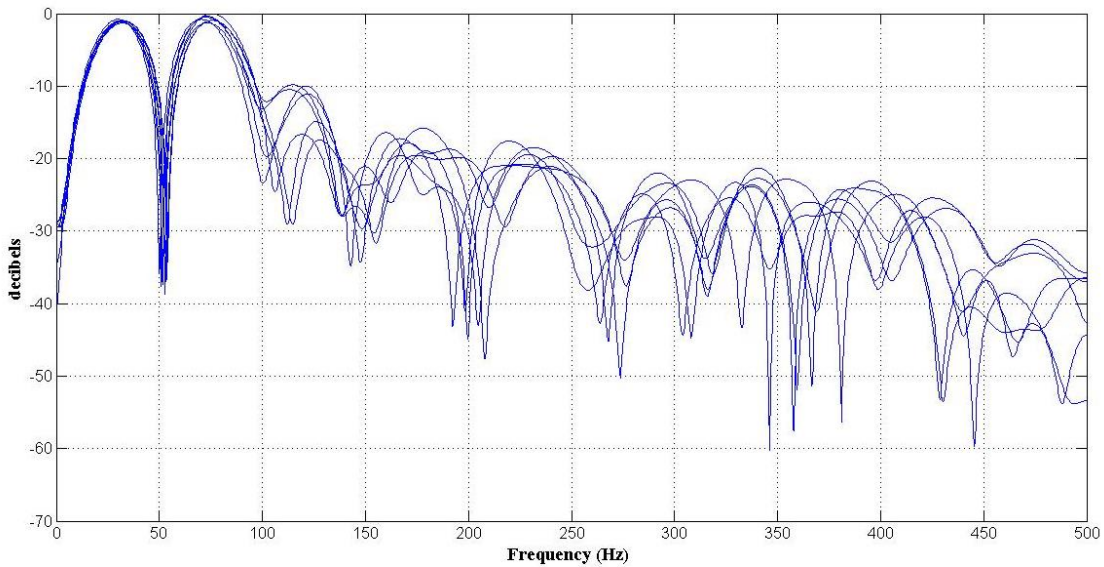
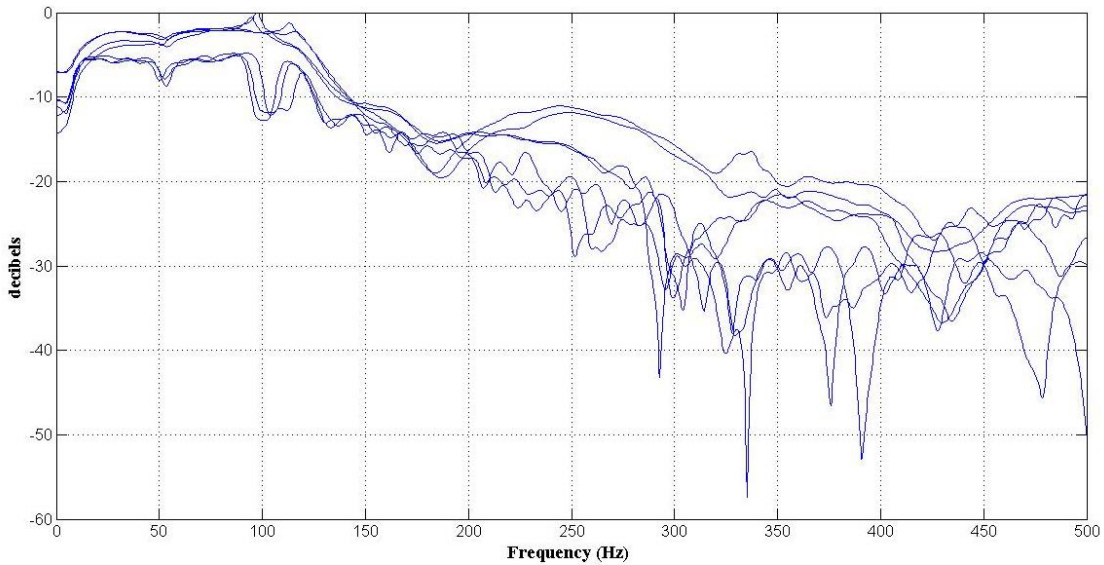
Hasil, Analisis dan Pembahasan: Spektrum Frekuensi Data Sintetik



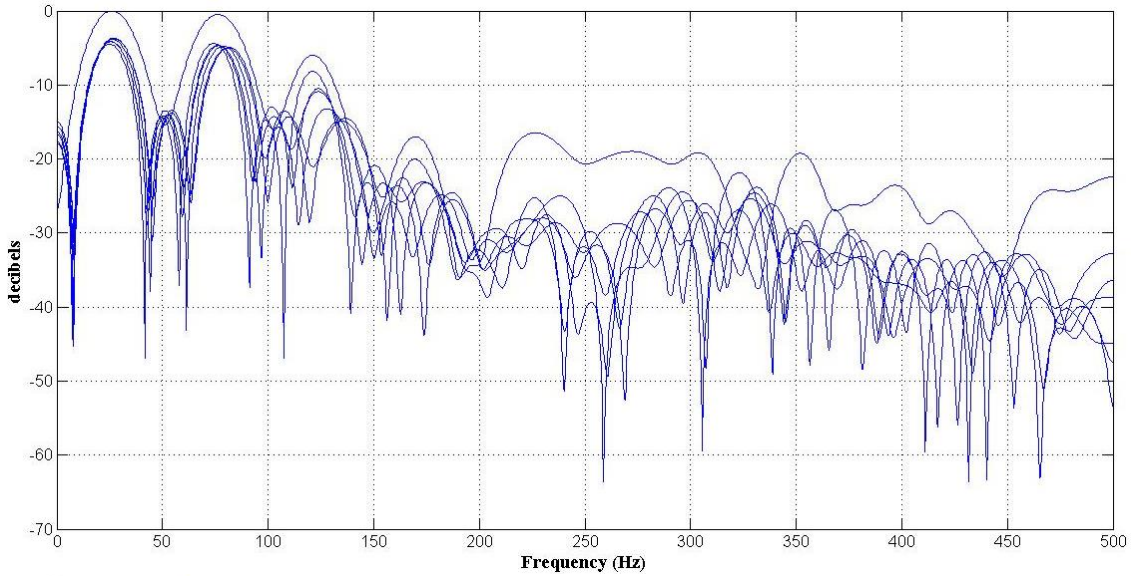


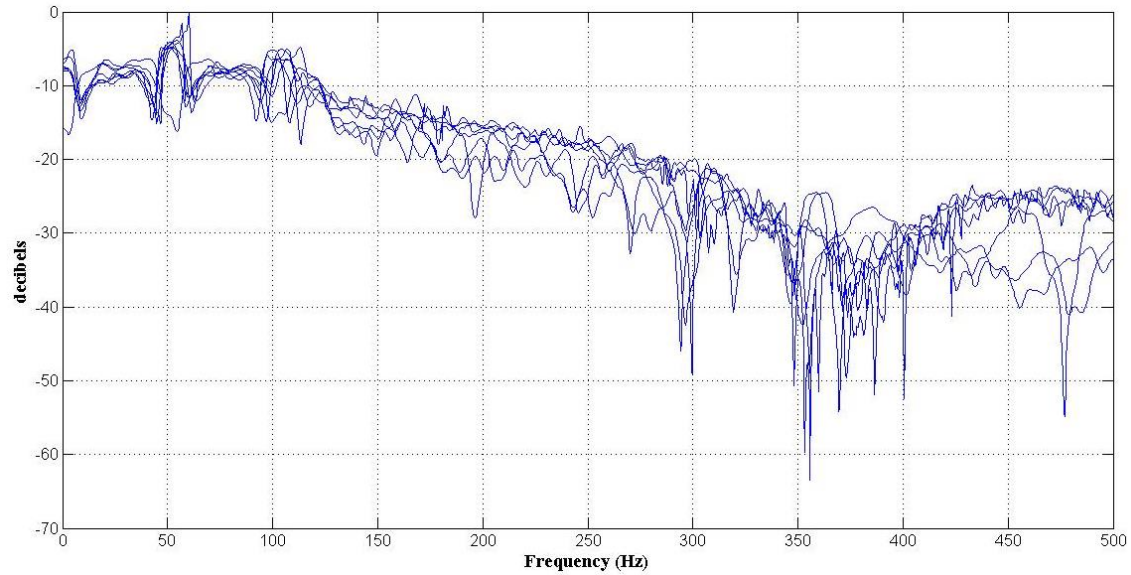
Spektrum Frekuensi data sintetik (atas)sebelum deghosting dan (bawah)sesudah deghosting Kedalaman sumber 15 dan kedalaman streamer 7.5 meter.

Efek ghost notch sudah tereliminasi oleh proses deghosting.

Dalam shot gather indikasi dari ghost sudah dihilangkan dengan semakin tipis nya pola reflektor.

Hasil, Analisis dan Pembahasan: Spektrum Frekuensi Data Sintetik



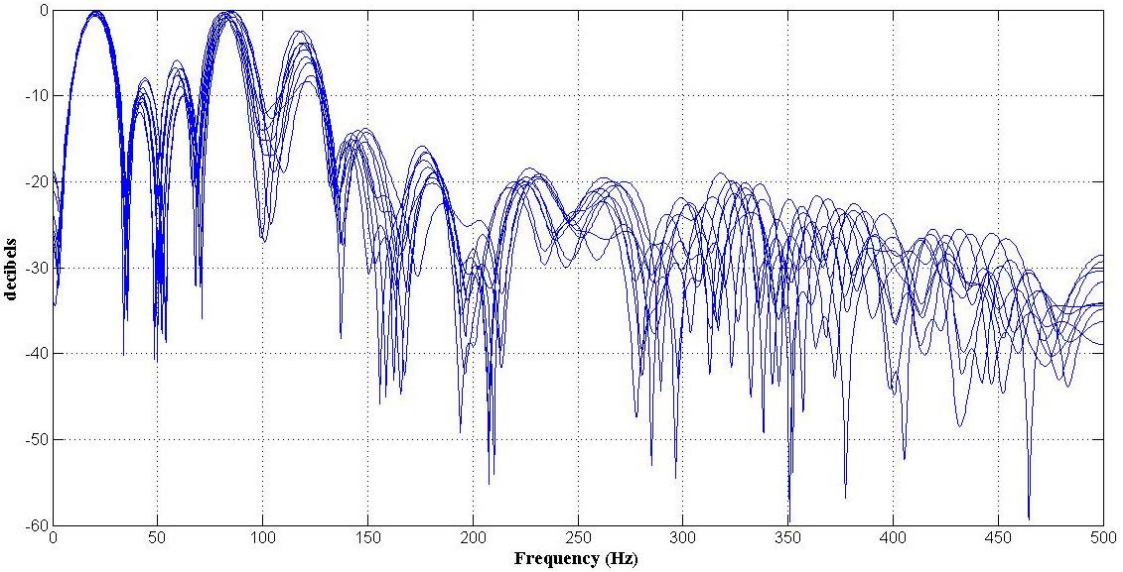


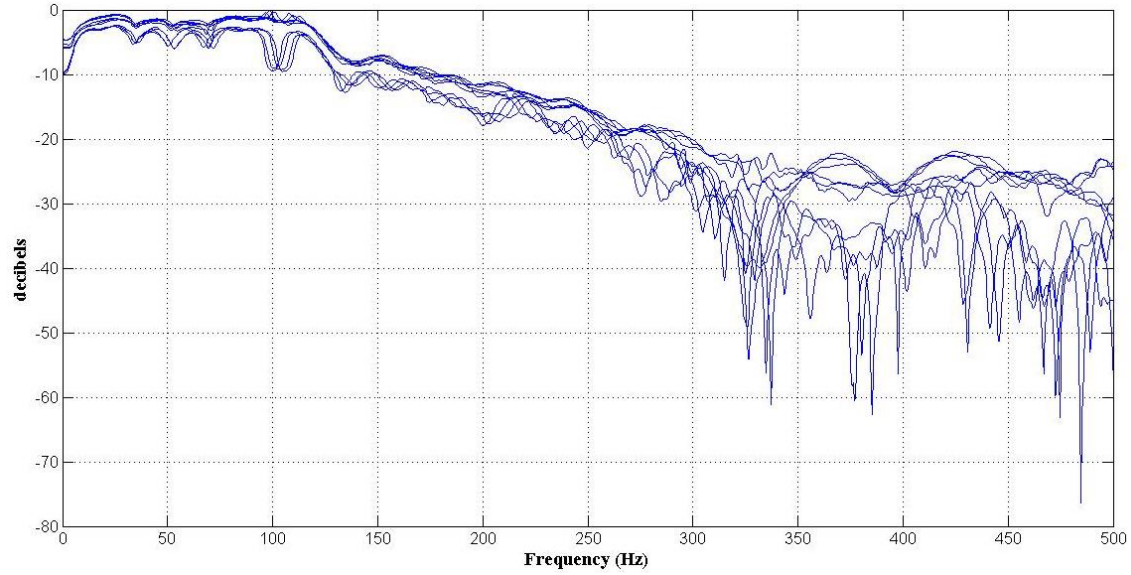
Spektrum Frekuensi data sintetik (atas)sebelum deghosting dan (bawah)sesudah deghosting Kedalaman sumber 15 dan kedalaman streamer 15 meter.

Efek ghost notch sudah tereliminasi oleh proses deghosting.

Dalam shot gather indikasi dari ghost sudah dihilangkan dengan semakin tipis nya pola reflektor.

Hasil, Analisis dan Pembahasan: Spektrum Frekuensi Data Sintetik



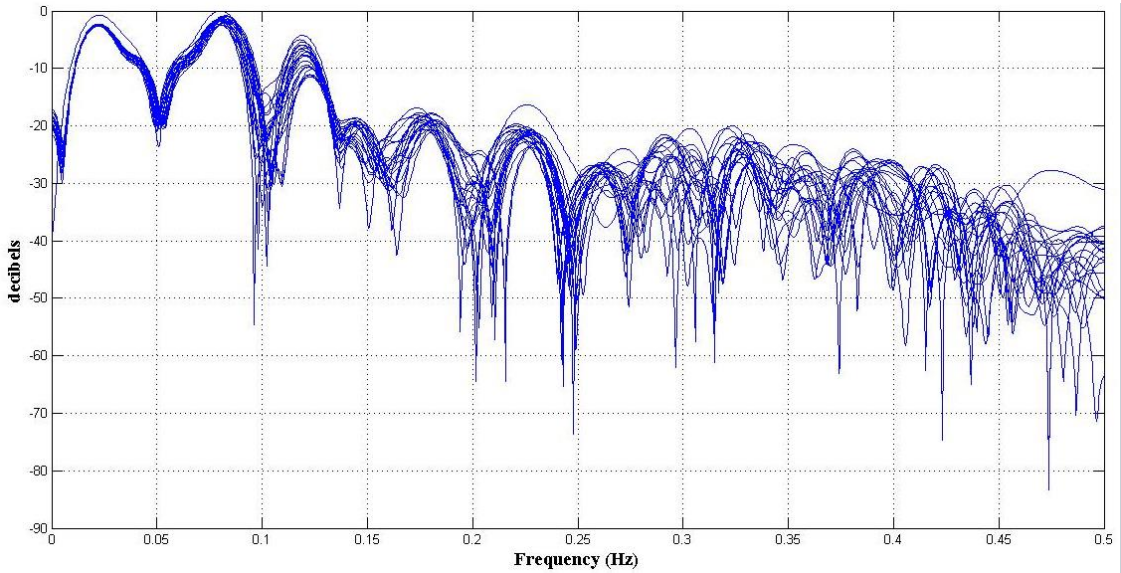


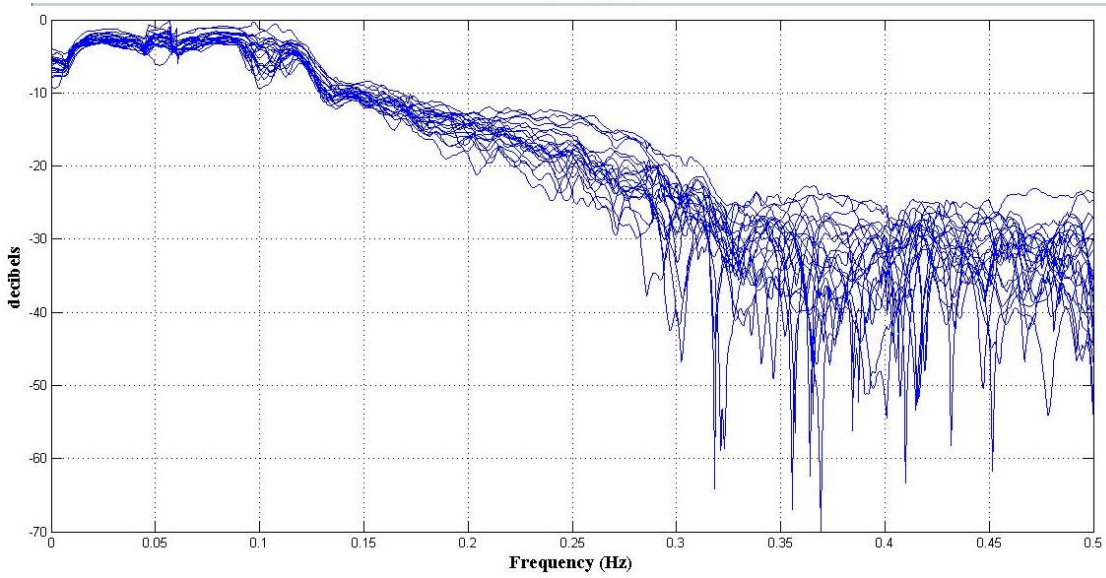
Spektrum Frekuensi data sintetik (atas)sebelum deghosting dan (bawah)sesudah deghosting Kedalaman sumber 15 dan kedalaman streamer 22.5 meter.

Efek ghost notch sudah tereliminasi oleh proses deghosting.

Dalam shot gather indikasi dari ghost sudah dihilangkan dengan semakin tipis nya pola reflektor.

Hasil, Analisis dan Pembahasan: Spektrum Frekuensi Data Sintetik



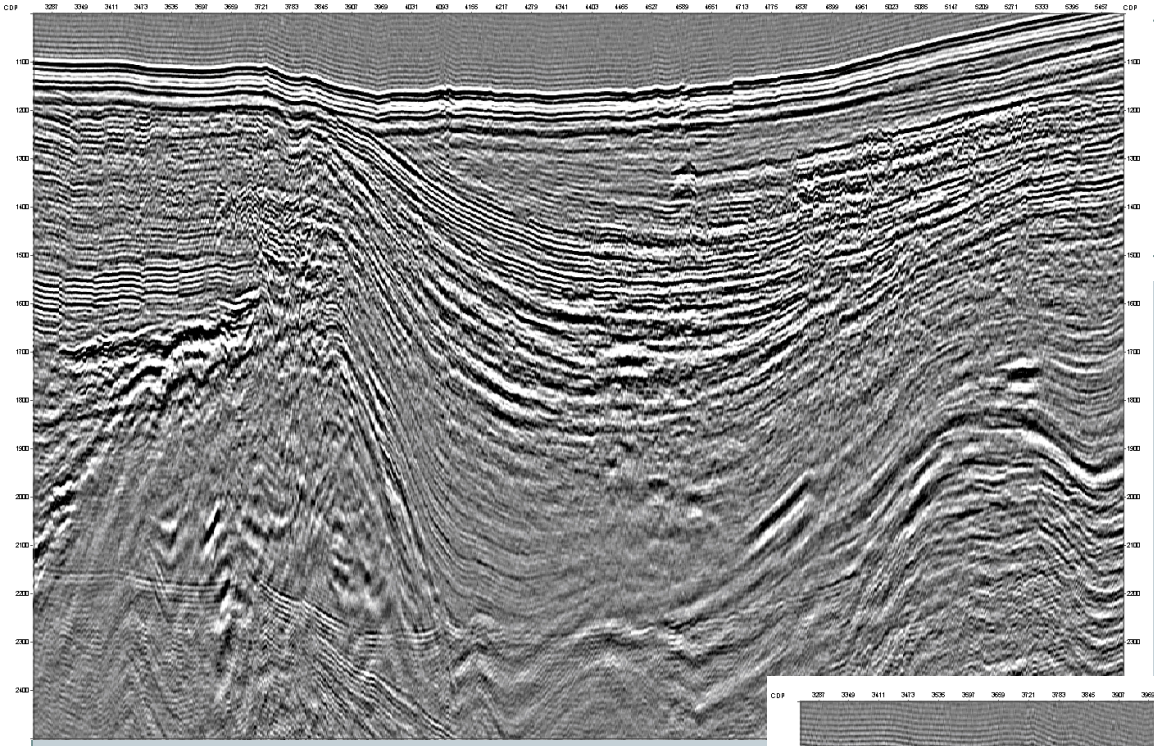


Spektrum Frekuensi data sintetik (atas)combined mode dan (bawah)combine mode dan deghosting

Dalam shot gather indikasi dari ghost sudah dihilangkan dengan semakin tipis nya pola reflektor.

Hasil dan Analisis :

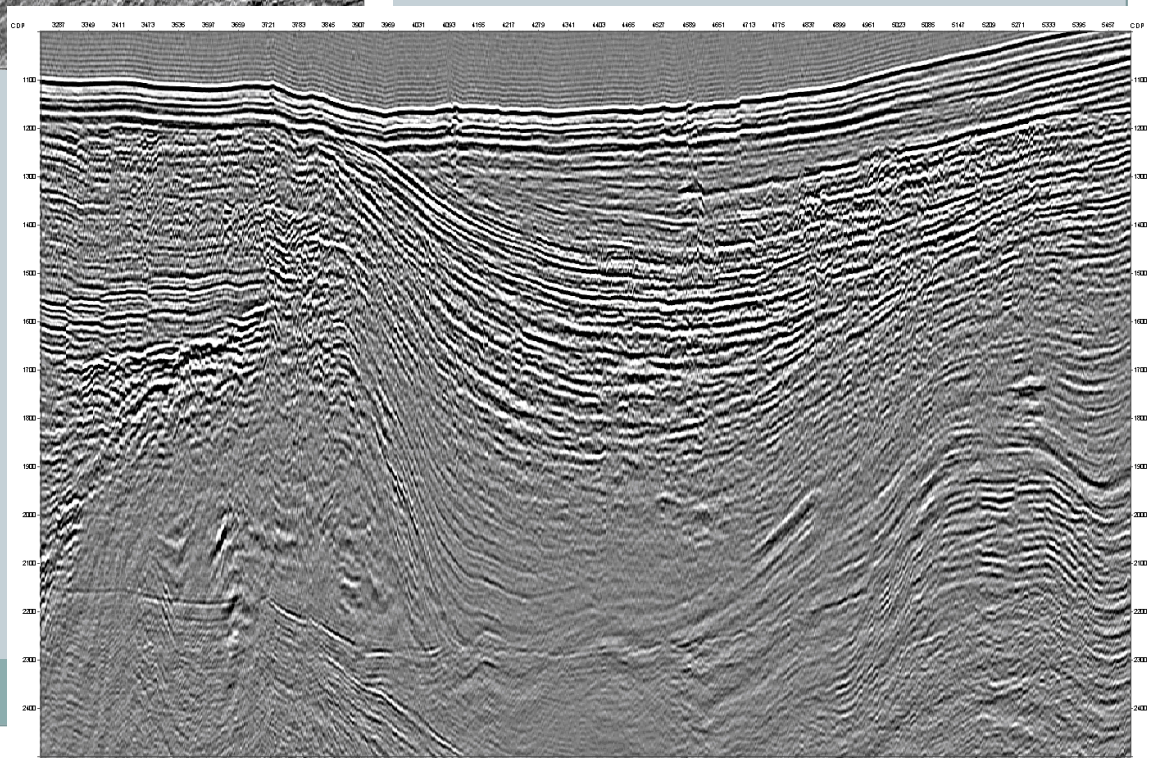
Data lapangan, deghosting pada setiap streamer

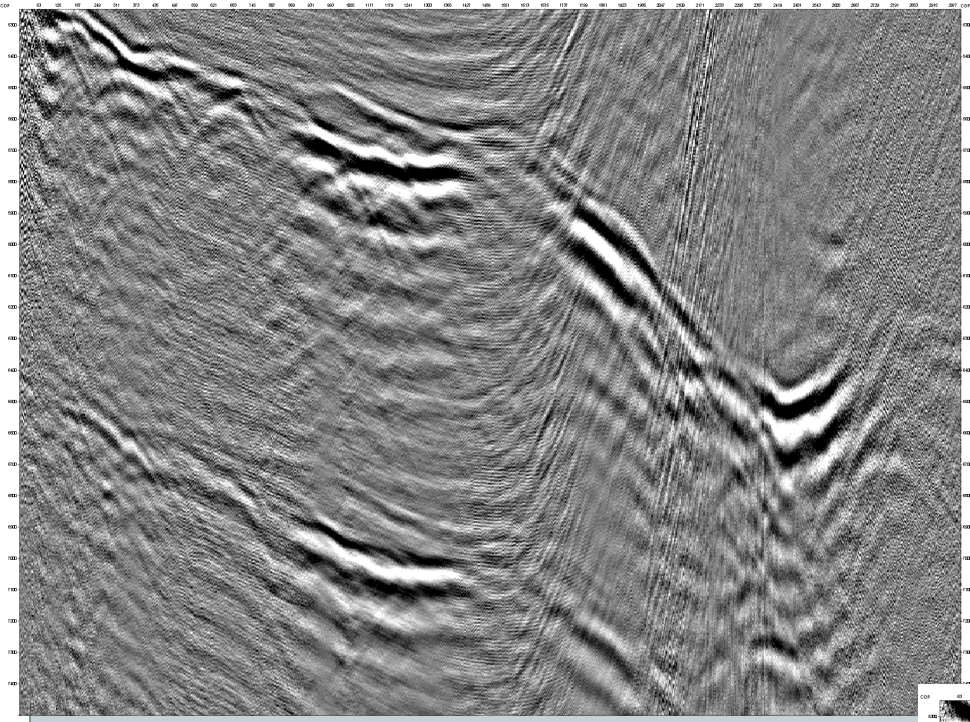


Untuk Target Dangkal: permukaan dasar laut-2.5 s

(atas) Penampang Seismik dengan kedalaman streamer 22.5 sebelum deghosting.

(atas) Penampang Seismik dengan kedalaman streamer 22.5 setelah deghosting.



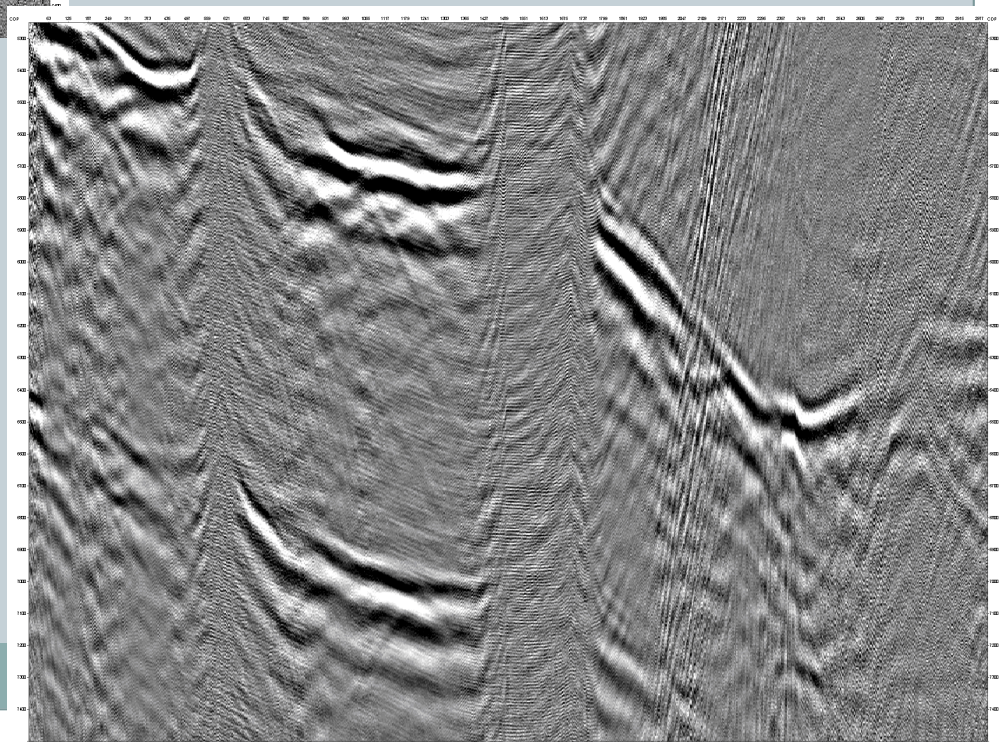


Hasil dan Analisis :
Data lapangan, deghosting pada setiap streamer

Untuk Target Dalam:
5.25 – 7.5 s

(atas) Penampang Seismik dengan kedalaman streamer 22.5 sebelum deghosting.

(atas) Penampang Seismik dengan kedalaman streamer 22.5 setelah deghosting.



Spektrum Frekuensi Data Lapangan Channel 1