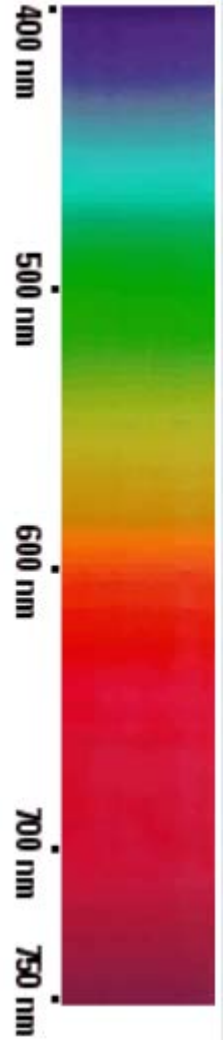
SEISMIC (GHOSTLY) APPARITION
«the act of becoming visible»

Lasse Amundsen, Åsmund Sjøen Pedersen & Johan Robertsson

INTRODUCTION

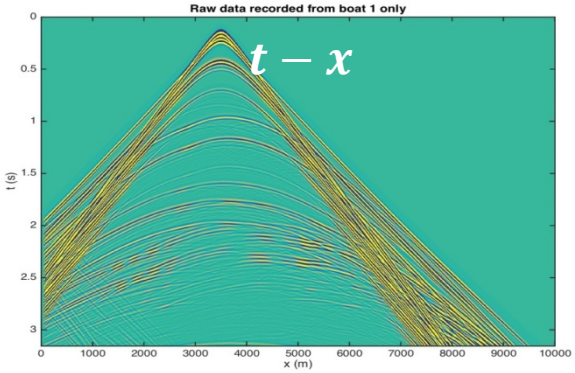
- Newton's "party boost" (1666-72): white light entering the prism, is separated into colors
- He introduced the word "spectrum" which means "ghostly apparition"
- We use seismic spectra and introduce you to seismic apparition where we use periodic source patterns in multishooting to separate (decode) data in f-k

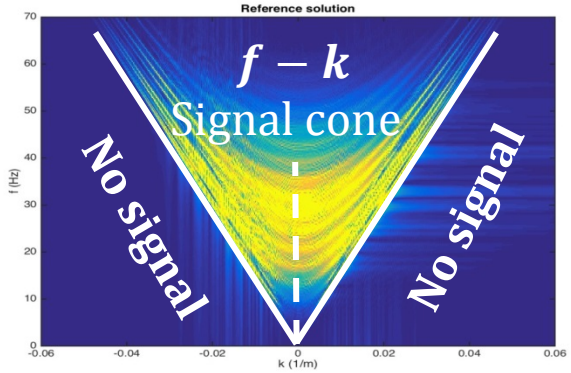


Statoil

CONVENTIONAL SAMPLING FREQUENCY-WAVENUMBER (*f-k*) SPECTRUM

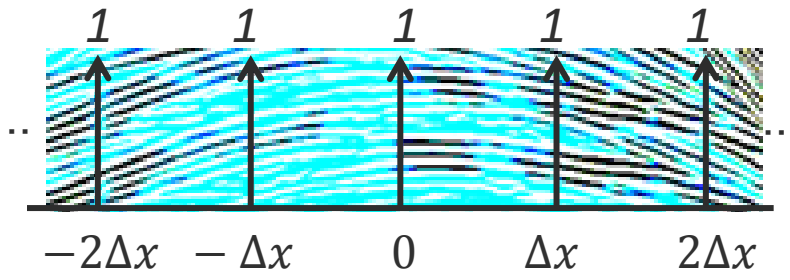
- In geosciences, we plot $t - x$ data in $f - k$ diagrams to examine the direction and apparent velocity of seismic waves $c_{apparent} = f/k$
- Seismic data are located in the signal cone (determined by water speed)
- We shall display common receiver gather (CRG) (one receiver, all shots) for
  - regular source
  - periodic source
  - sum of regular and periodic source



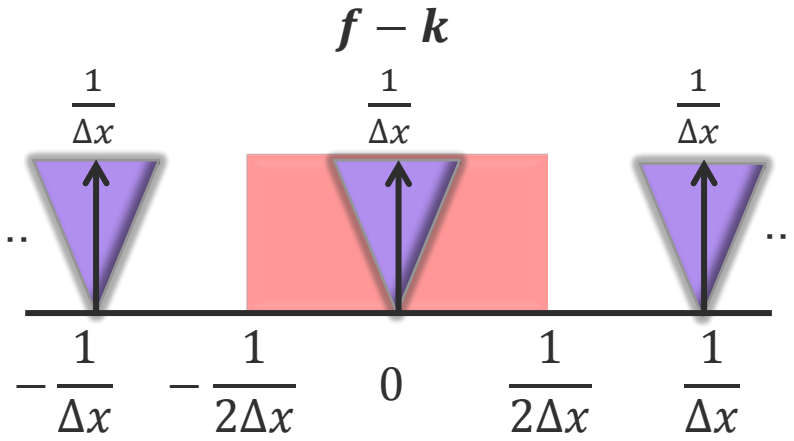


Statoil

Regular source sampling: *...,1,1,1,1,1,...* (wavefield sampled at Δx in CRG)



$$\sum_{n=-\infty}^{\infty} \delta(x - n\Delta x)$$



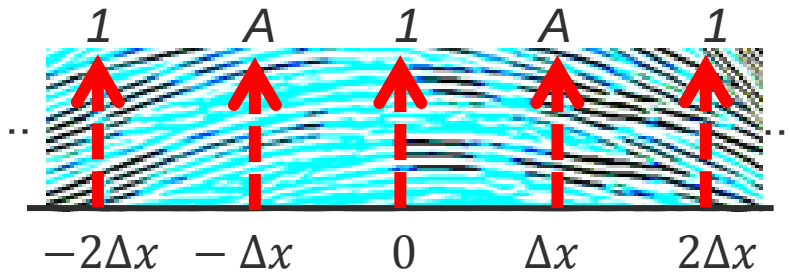
$$\frac{1}{\Delta x} \sum_{n=-\infty}^{\infty} \delta\left(k - \frac{n}{\Delta x}\right)$$

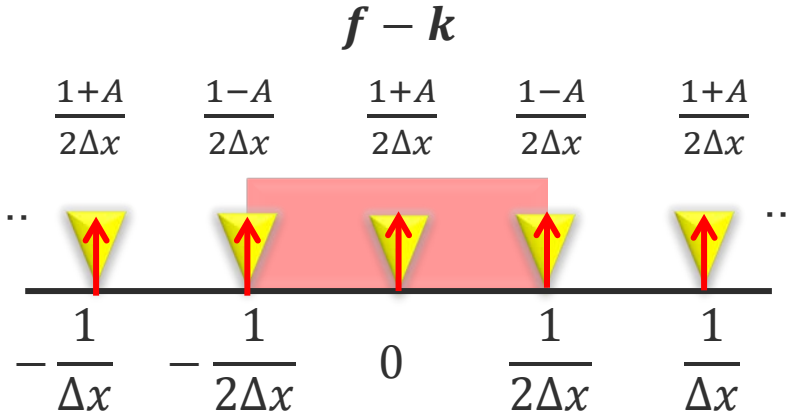
Spatial sampling frequency: $k_s = \frac{1}{\Delta x}$

Spatial Nyquist frequency: $k_N = \frac{1}{2\Delta x}$

Statoil

Periodic source sampling: *...,1,A,1,A,1,...* (sum of two wavefields each sampled at $2\Delta x$)





$$\sum_{n=-\infty}^{\infty} \delta(x-2n\Delta x) + A\,\delta(x-\Delta x-2n\Delta x)$$

$$\frac{1}{2\Delta x}\sum_{n=-\infty}^{\infty}(1+A(-1)^n)\delta\left(k-\frac{n}{2\Delta x}\right)$$

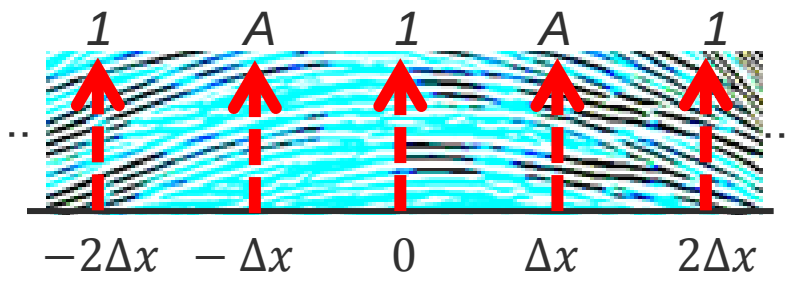
$$k_s = \frac{1}{2\Delta x}$$

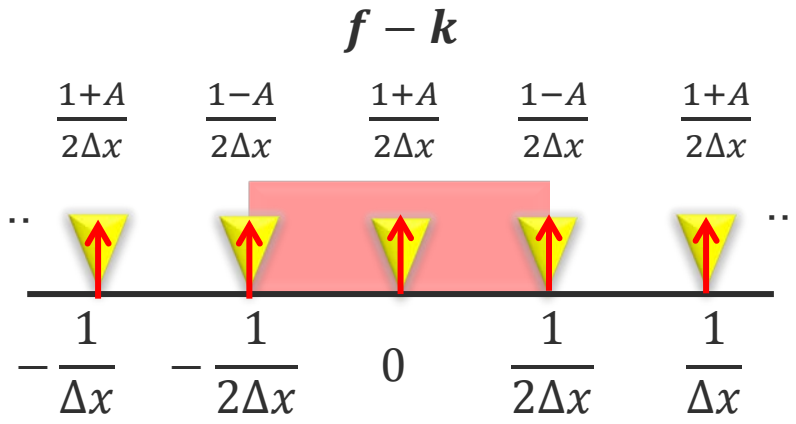
Examples:

$A=\exp(i\omega T)$	time shift
$A=1/2$	reduced voulme
$A=-1$	polarity reversal
$A=0$	no shooting
$A=1$	regular sampling

Statoil

Periodic source sampling: *...,1,A,1,A,1,...* (sum of two wavefields each sampled at $2\Delta x$)



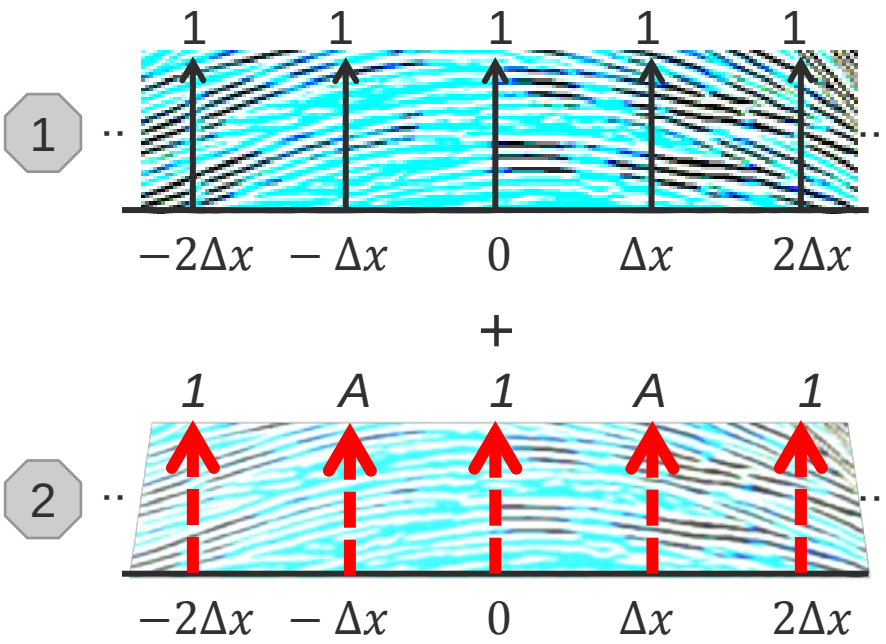


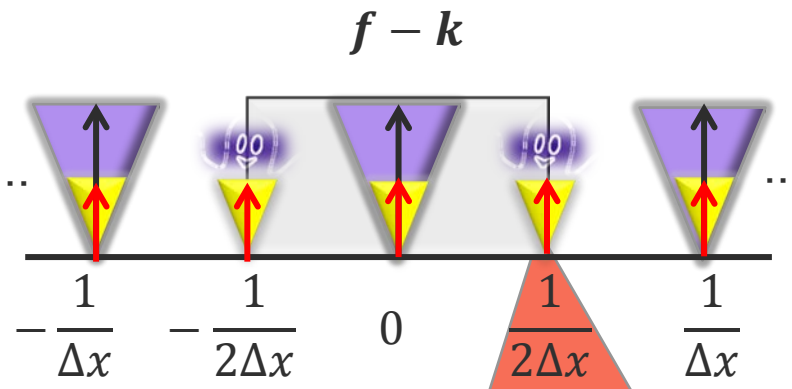
Observation: "Unshifted" energy around k=0 can be predicted from the portion that is "shifted" to $\frac{1}{2\Delta x}$.

$$\frac{1+A}{2\Delta x} = \frac{1-A}{2\Delta x} \quad \frac{1+A}{1-A}$$

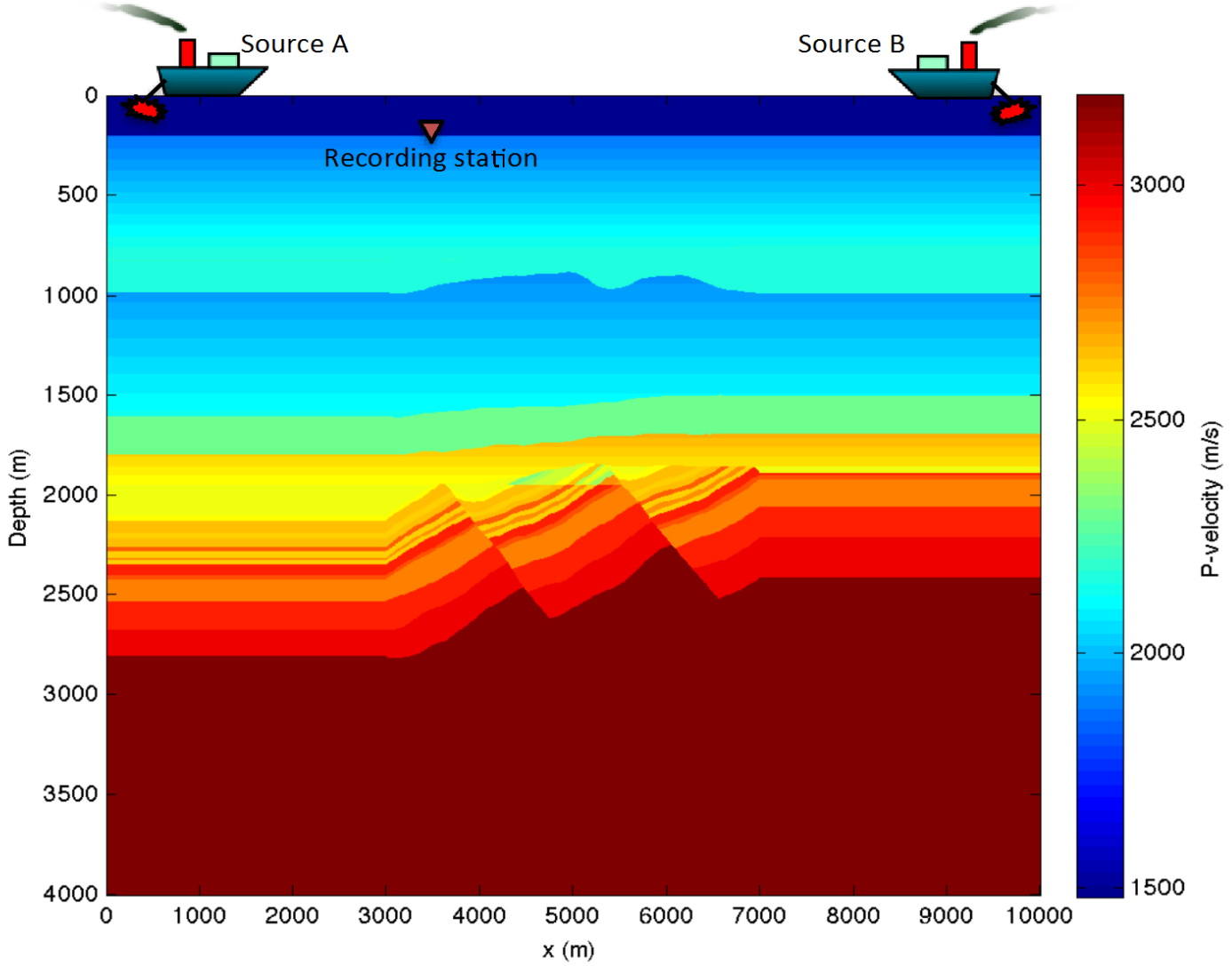
Statoil

Regular source sampling of wavefield 1 + periodic source sampling of wavefield 2 = Seismic apparition



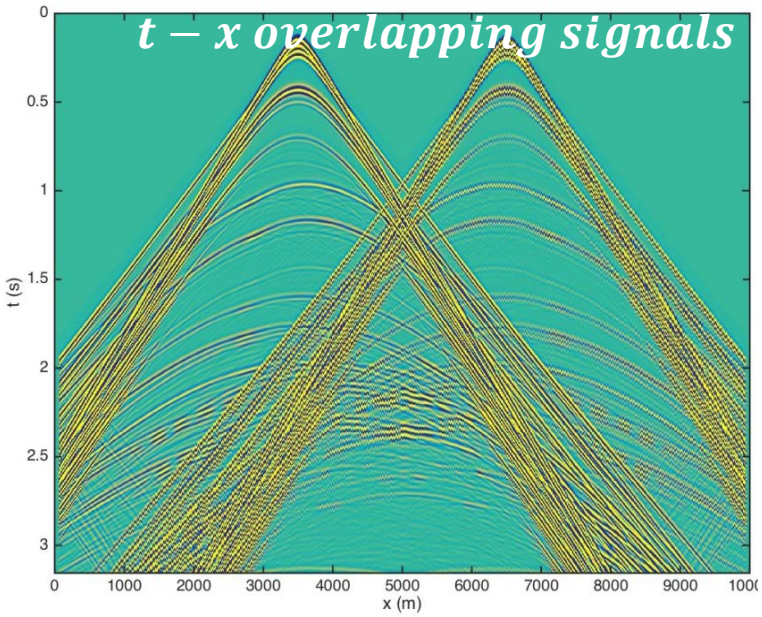


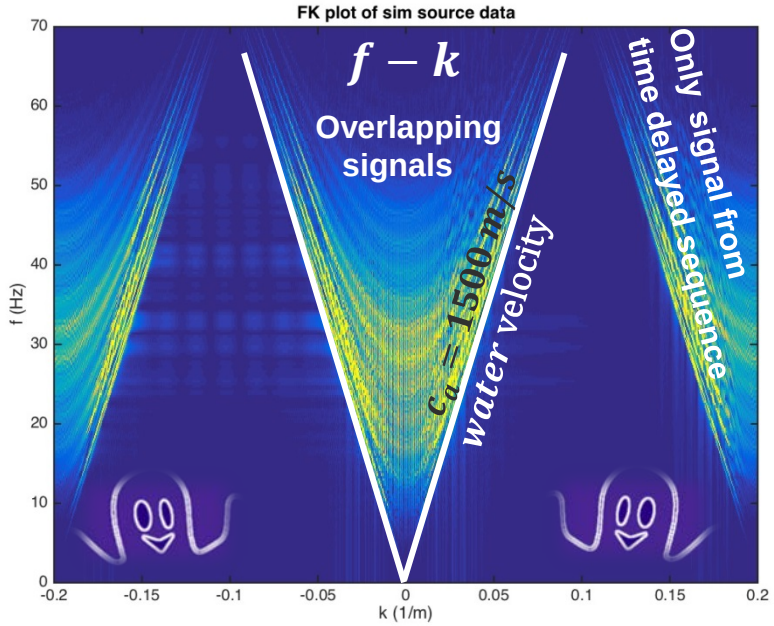
«Ghost spectrum» of wavefield 2 becomes isolated and is known in *f-k*!
Can compute wavefield 2 in cone around k=0.
Then wavefield 1 = sum – wavefield 2


Source A
Source B
Recording station
Depth (m)
0
500
1000
1500
2000
2500
3000
3500
4000
x (m)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
P-velocity (m/s)
1500
2000
2500
3000

Statoil

TWO SIMULTANEOUS SOURCES (SIMSOR)
REGULAR + PERIODIC TIME DELAY

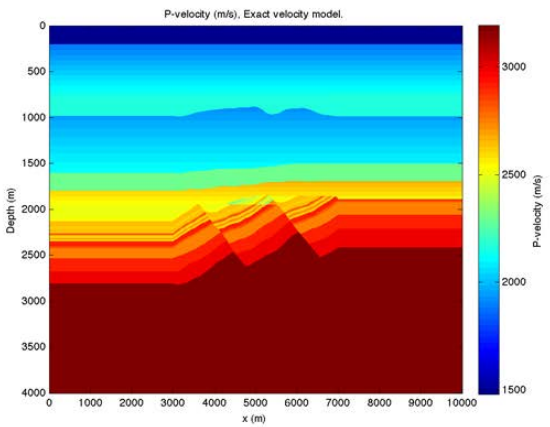


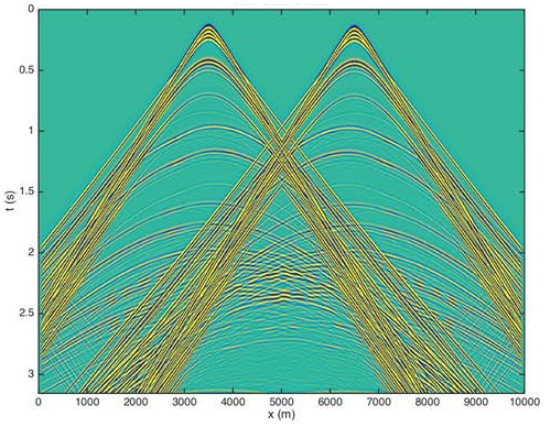


Ghost spectrum is only caused by and related to the source sequence with time delay, i.e.,
Ghost spectrum contains only information about the periodic time delay sequence.
We can therefore separate the source sequences.

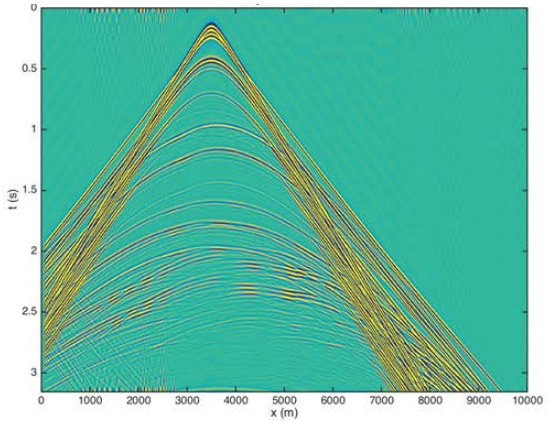
SIMSOR SEPARATION

SIMSOR CRG

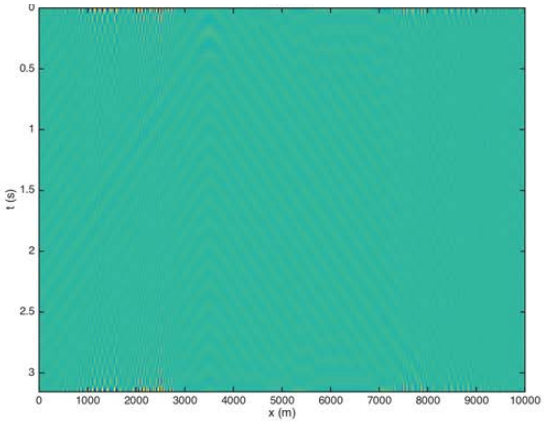




SIMSOR SEPARATION

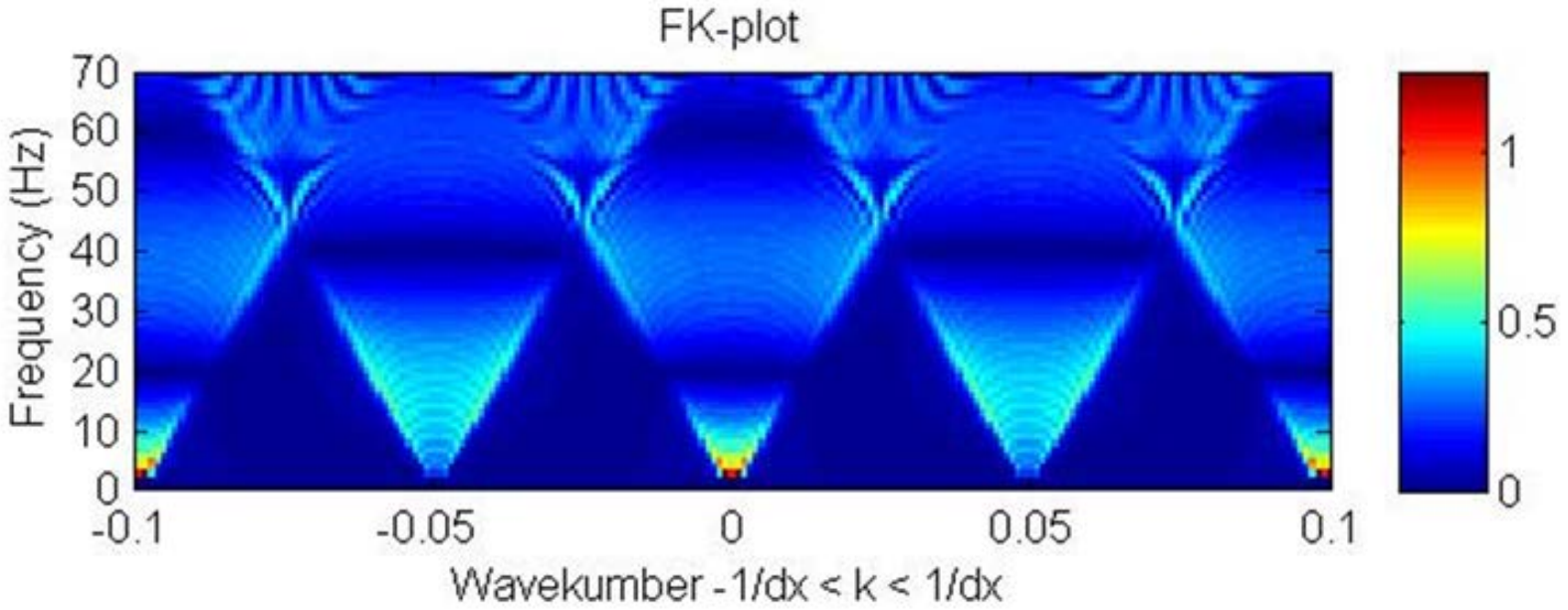


DIFFERENCE



Statoil

Need for de-aliasing – next talk



Statoil

REFERENCES

1. Robertsson, J. O. A., L Amundsen, Å Sjøen Pedersen, 2016, A seismic shift: Wavefield signal apparition: Submitted to Journal.
2. Robertsson, J. O. A., L. Amundsen, and Å. Sjøen Pedersen, 2016, Wavefield signal apparition, Part I: Theory: EAGE, Vienna.
3. Sjøen Pedersen, Å, L. Amundsen, and J. O. A. Robertsson, 2016, Wavefield signal apparition, Part II: Applications: EAGE, Vienna.
4. Robertsson, , J. O. A., L Amundsen, Å Sjøen Pedersen, F Andersson, D-J van Manen, 2016, Wavefield signal apparition: Simultaneous source separation: SEG
5. van Manen, D-J, J.O. A. Robertsson, F Andersson, K Eggenberger, and L Amundsen: Aperiodic wavefield signal apparition: dealiased simultaneous source separation: SEG
6. Andersson F, K Eggenberger, D-J van Manen, J.O. A. Robertsson, L. Amundsen, Seismic apparition dealiasing using directionality regularization: SEG
7. van Manen, D-J, J.O. A. Robertsson, F Andersson, K Eggenberger, and L Amundsen: Aperiodic signal apparition – De-aliased sim-source separation: ROSE meeting, NTNU.