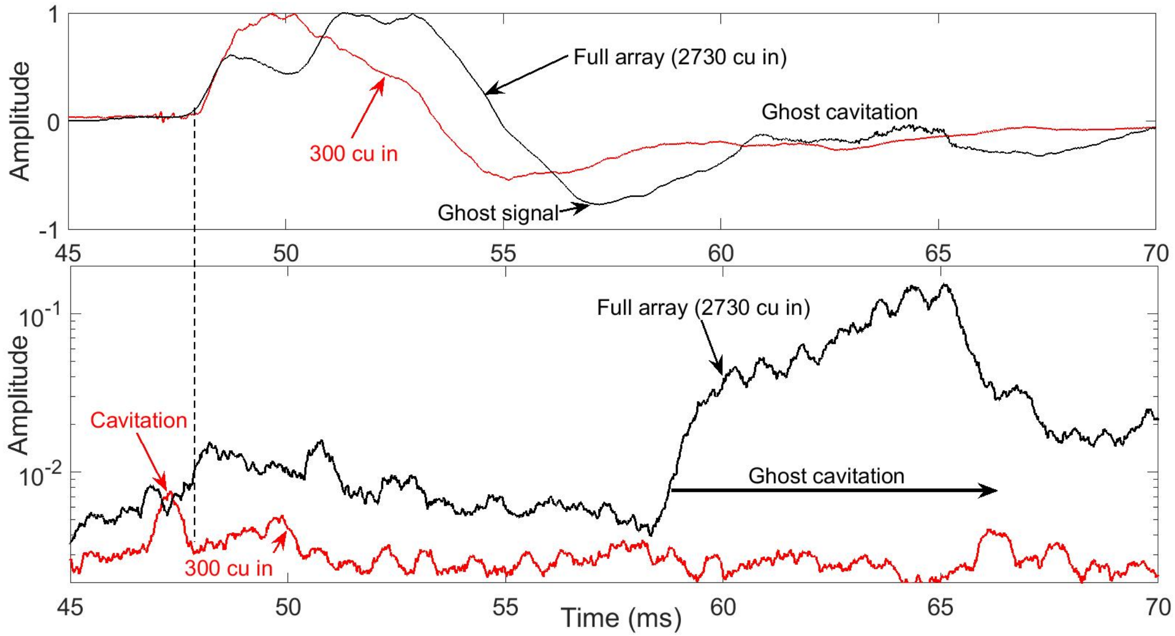
Modeling time-varying diffraction caused by ghost-cavitation

Kjetil Eik Haavik, Babak Khodabandeloo and Martin Landrø

Introduction



High-pass filter 30 kHz + abs. val. + smoothing

Figure from Landrø et al. (2016)

Ghost cavitations

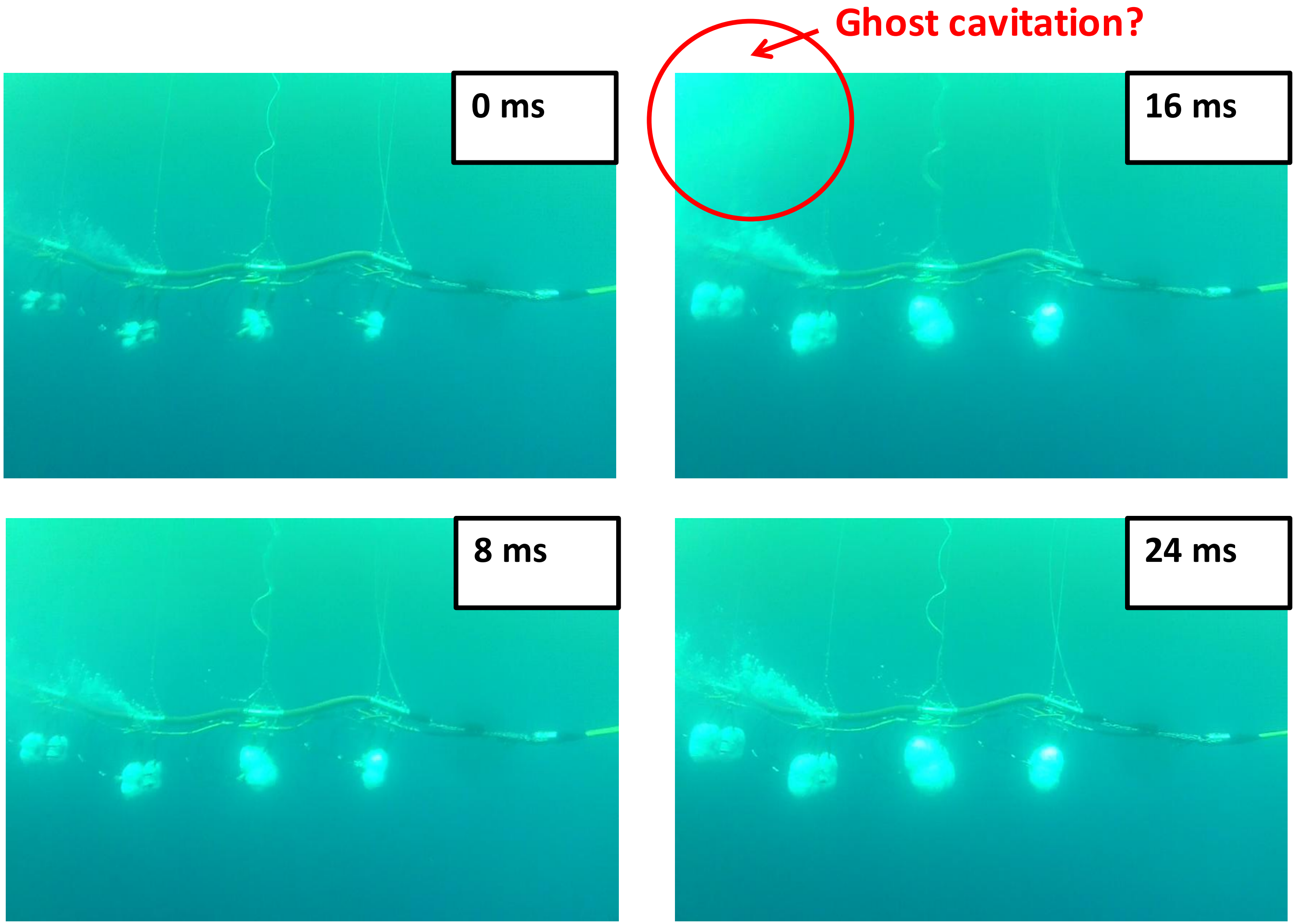


Figure from Landrø et al. (2016)

Cavitation cloud from air-gun array

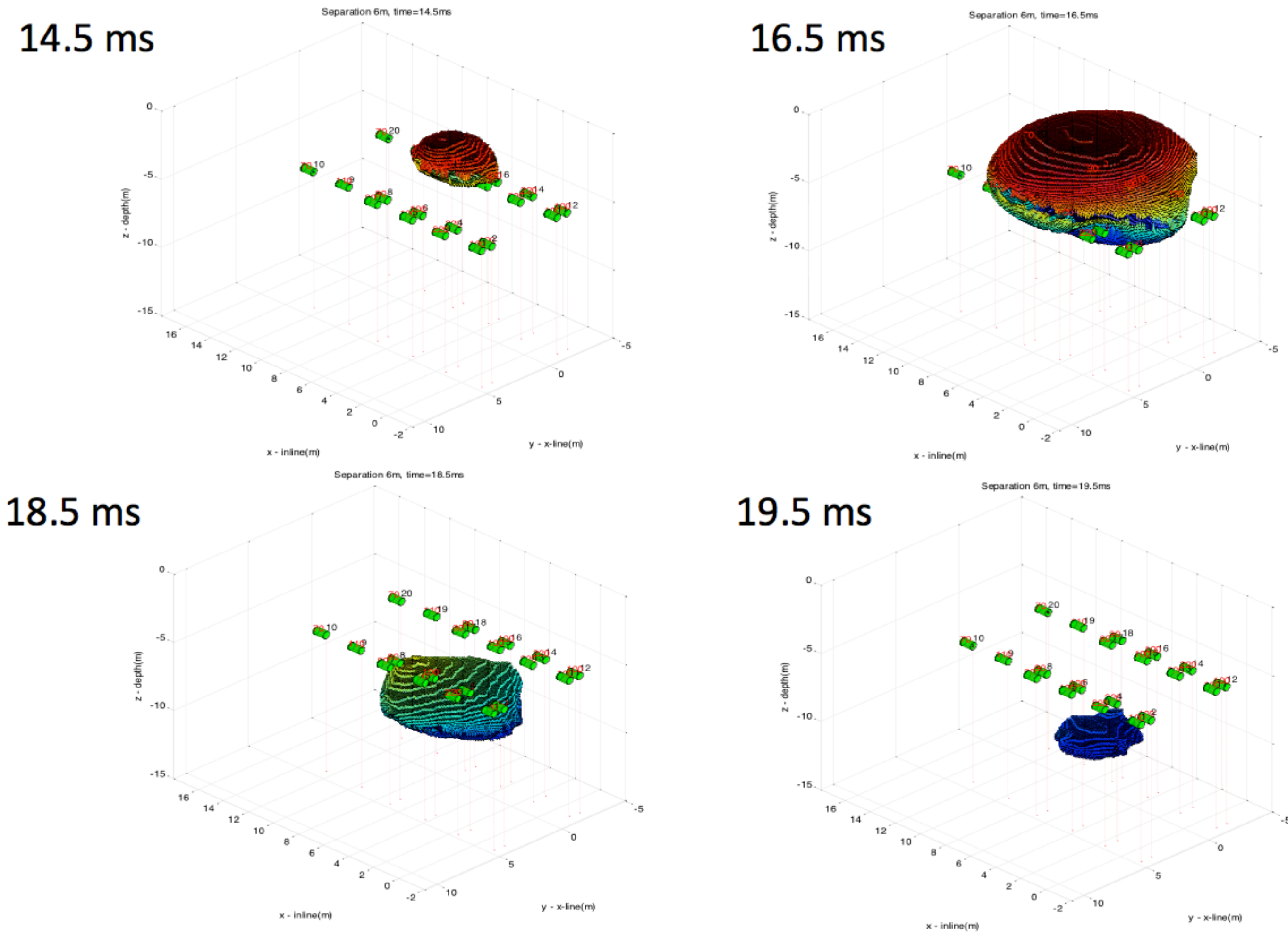
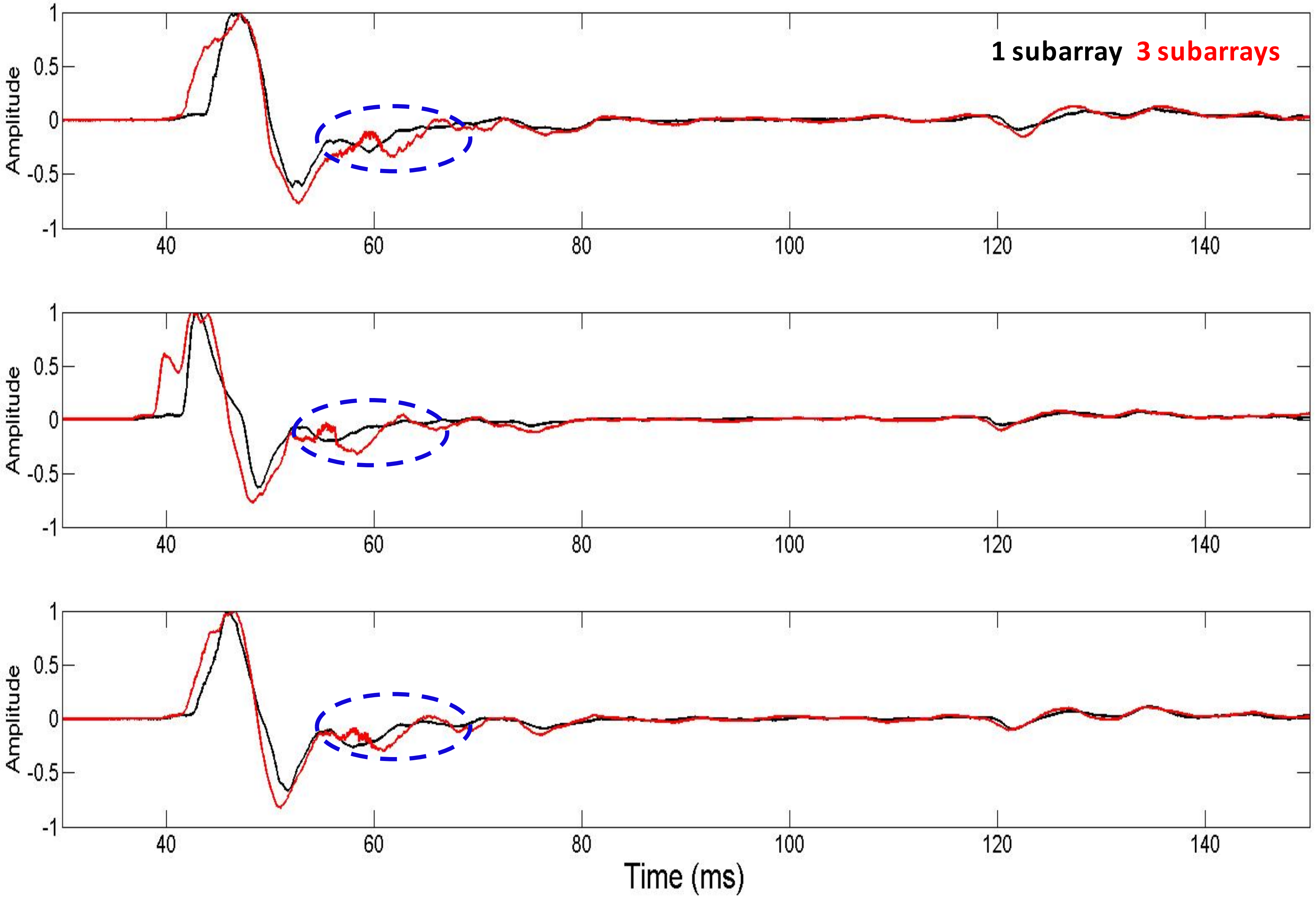
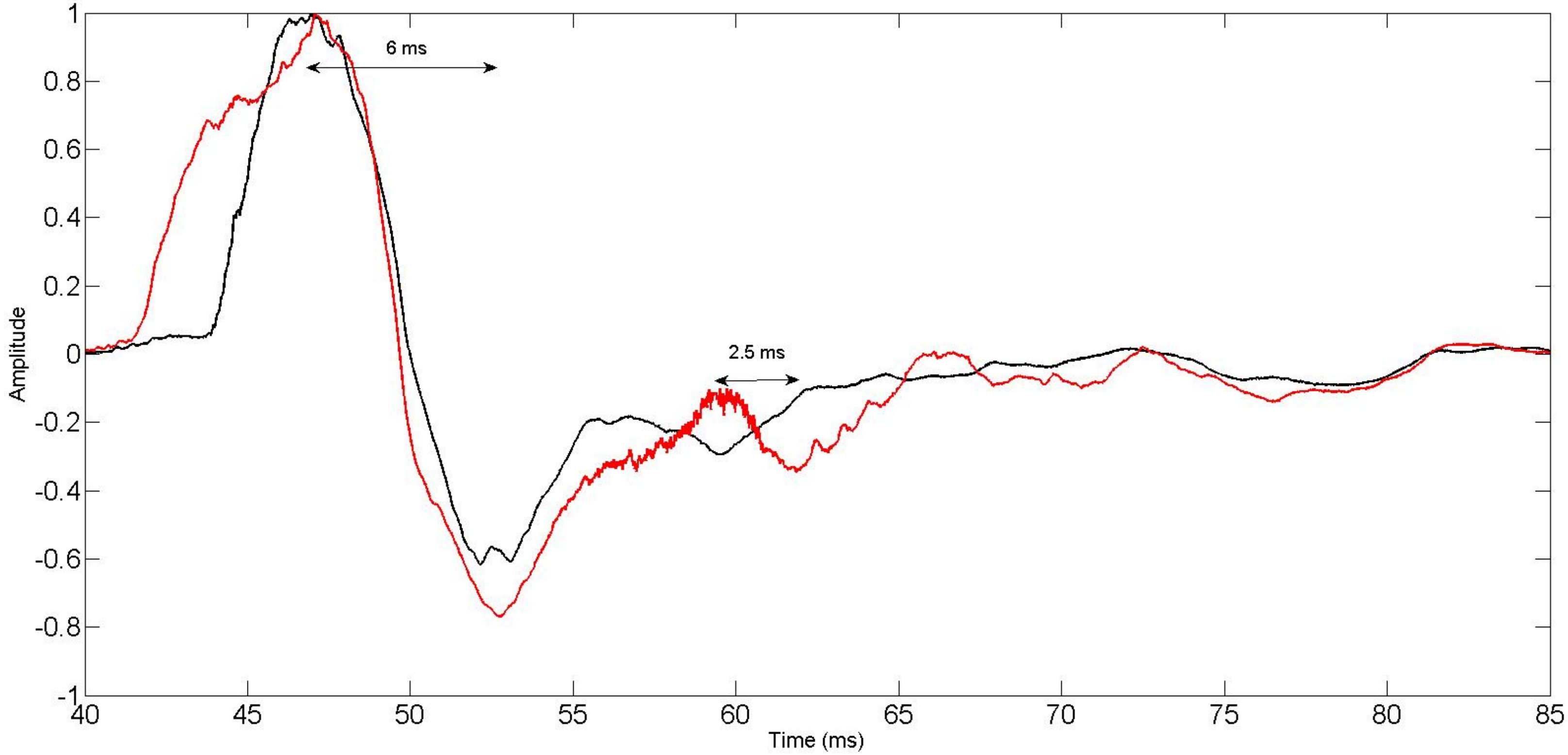


Figure from Landrø et al. (2016)

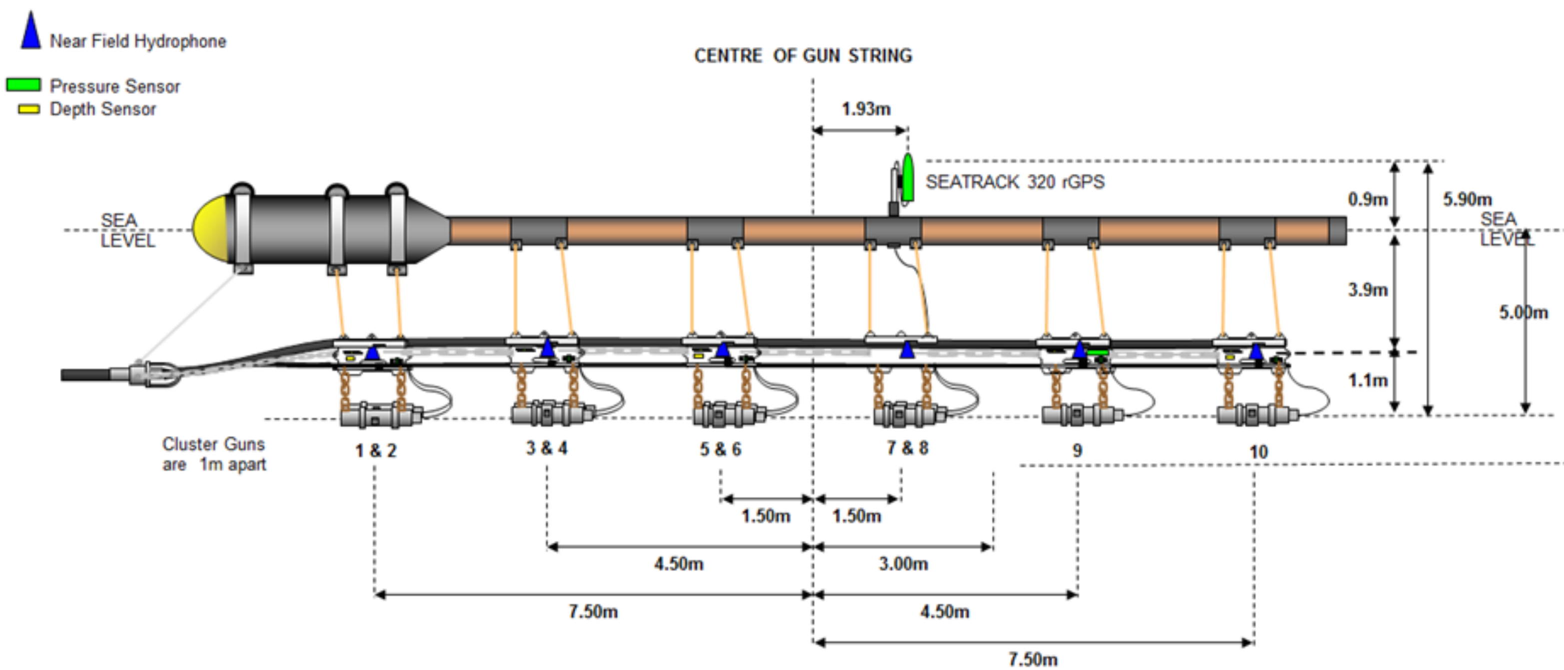
3 shots showing large differences around the ghost cavitation signal – caused by ghost diffraction?



Cavity diffraction + ghost?



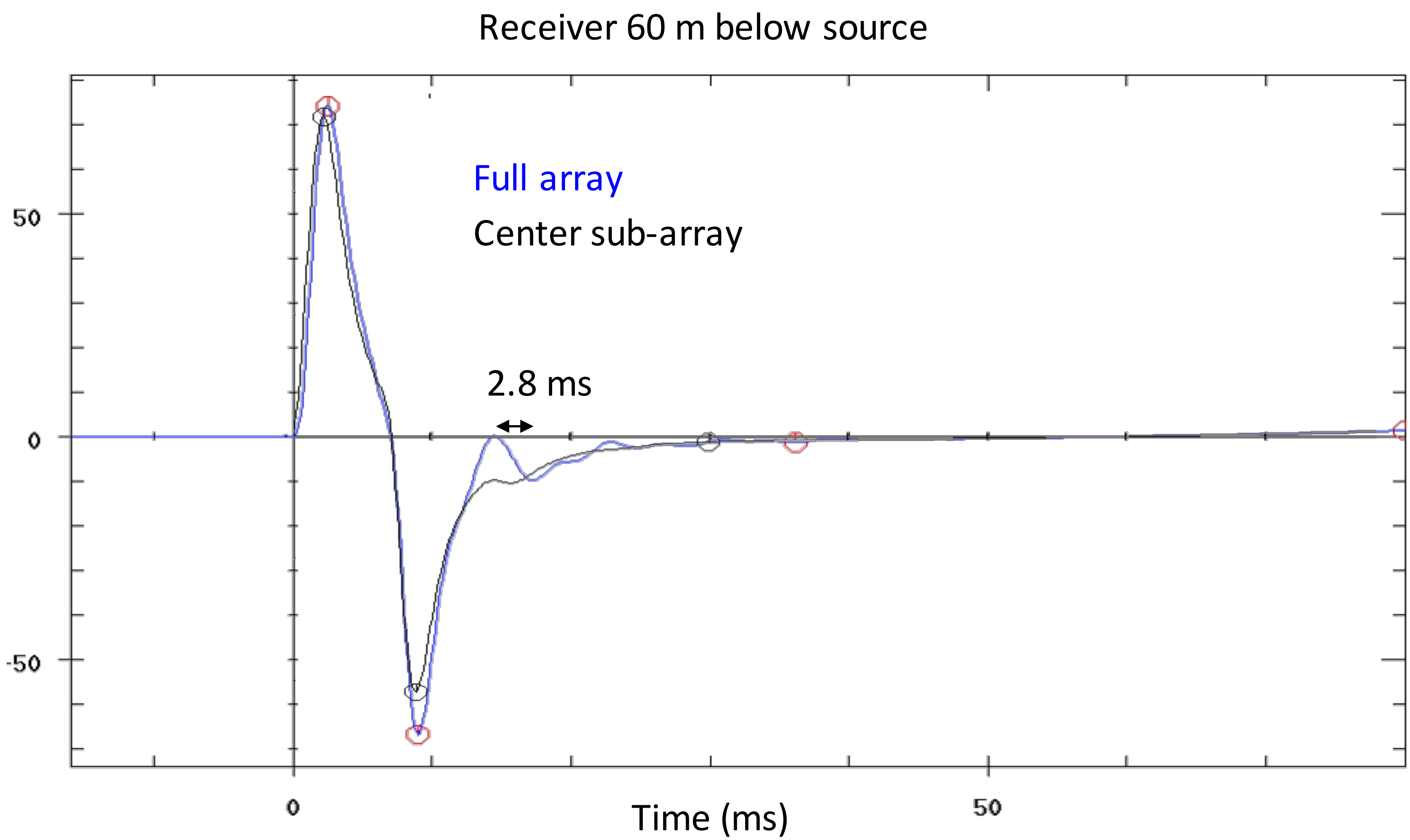
Air-gun modeling from Nucleus



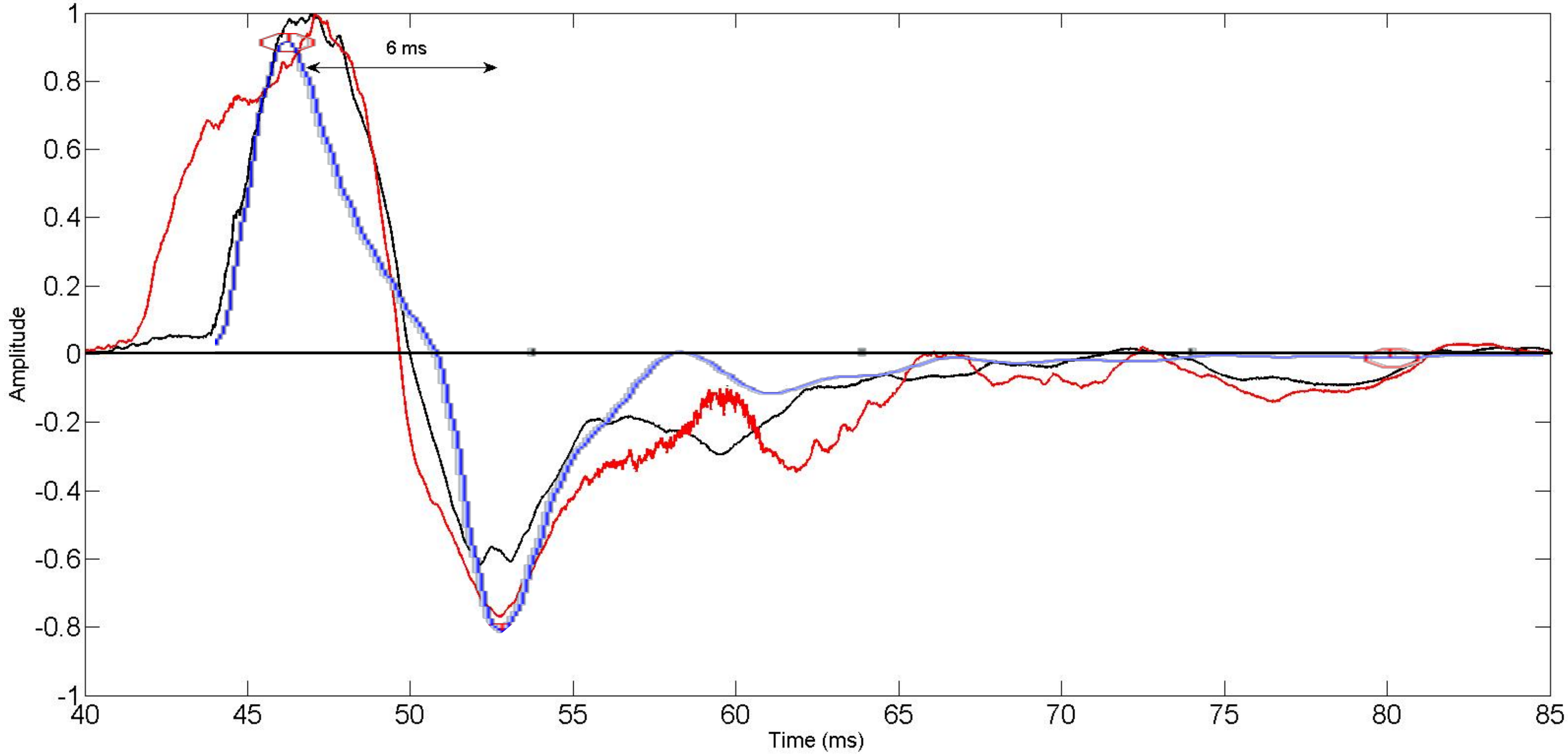
GUN VOLUMES (Cubic inches)

ARRAY 1	250	70	150	100	100	70
	250	70	150	100		
ARRAY 2	100	100	300	300	150	100
	100	100	300	300		
ARRAY 3	250	70	150	100	100	70
	250	70	150	100		

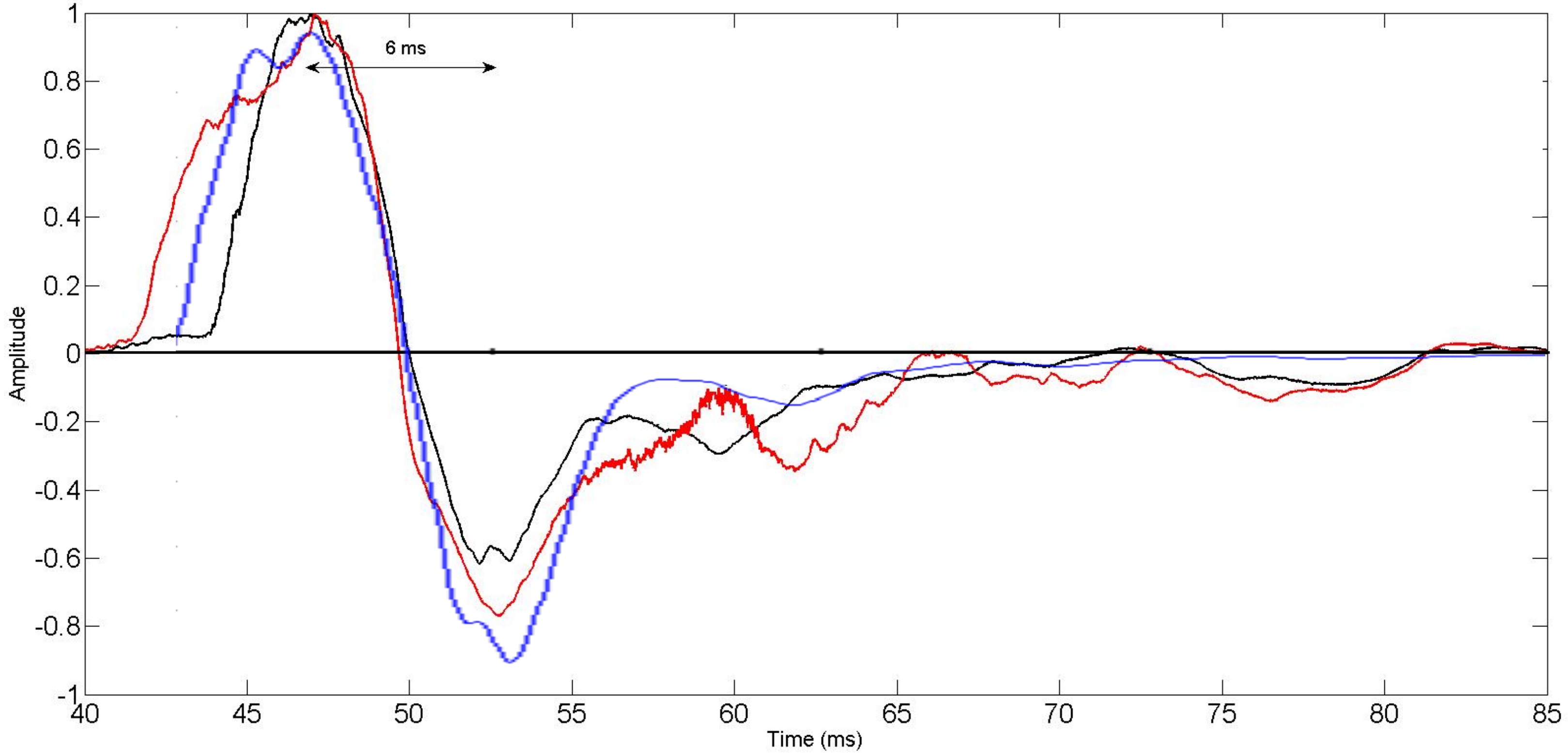
Air-gun modeling from Nucleus



Vertical below source



20 m to X-line direction



Modeling of time-varying models

$$\rho \frac{\partial^2 \mathbf{u}}{\partial t^2} = -\nabla p \qquad K = K(\mathbf{x}, t)$$

$$p = -K \nabla \mathbf{u} \qquad \rho = \rho(\mathbf{x}, t)$$

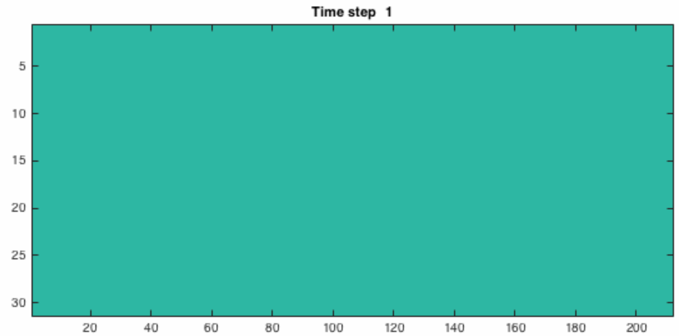
$$\boxed{\nabla^2 p - \frac{\rho}{K}\frac{\partial^2 p}{\partial t^2} = \frac{\nabla\rho \cdot \nabla p}{\rho} - 2\frac{\rho}{K}\frac{\partial K}{\partial t}\left(\frac{1}{K^2}\frac{\partial K}{\partial t}p - \frac{1}{K}\frac{\partial p}{\partial t}\right) + \frac{\rho}{K^2}\frac{\partial^2 K}{\partial t^2}p}$$

Non-linear PDE → High-frequency variations in model may influence the low-frequencies of the pressure

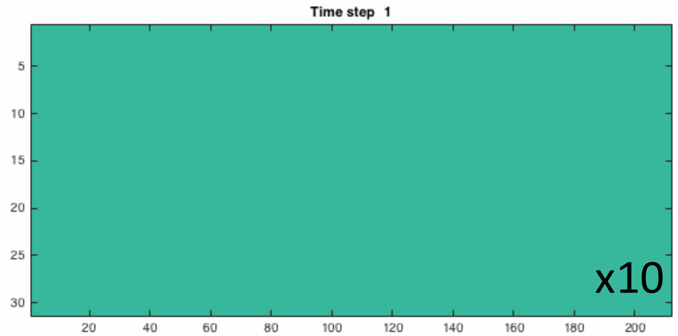
- Assume ρ and K is known for all times and positions
- Assume low-freq. variations in pressure does not influence ρ or K
- Solve in V-P - scheme

FD-Modeled wavefields

Background wavefield
No diffractor

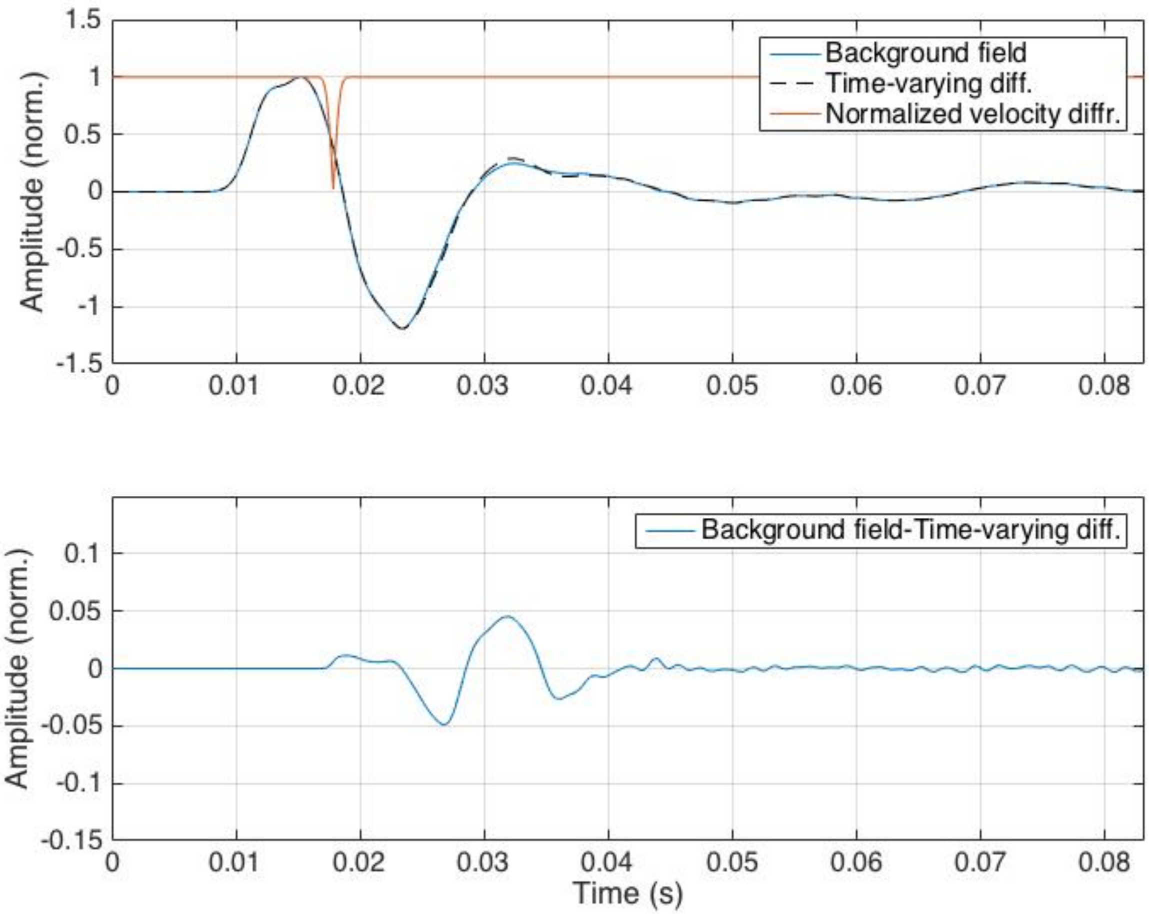


Difference between background field and field with time varying diff.

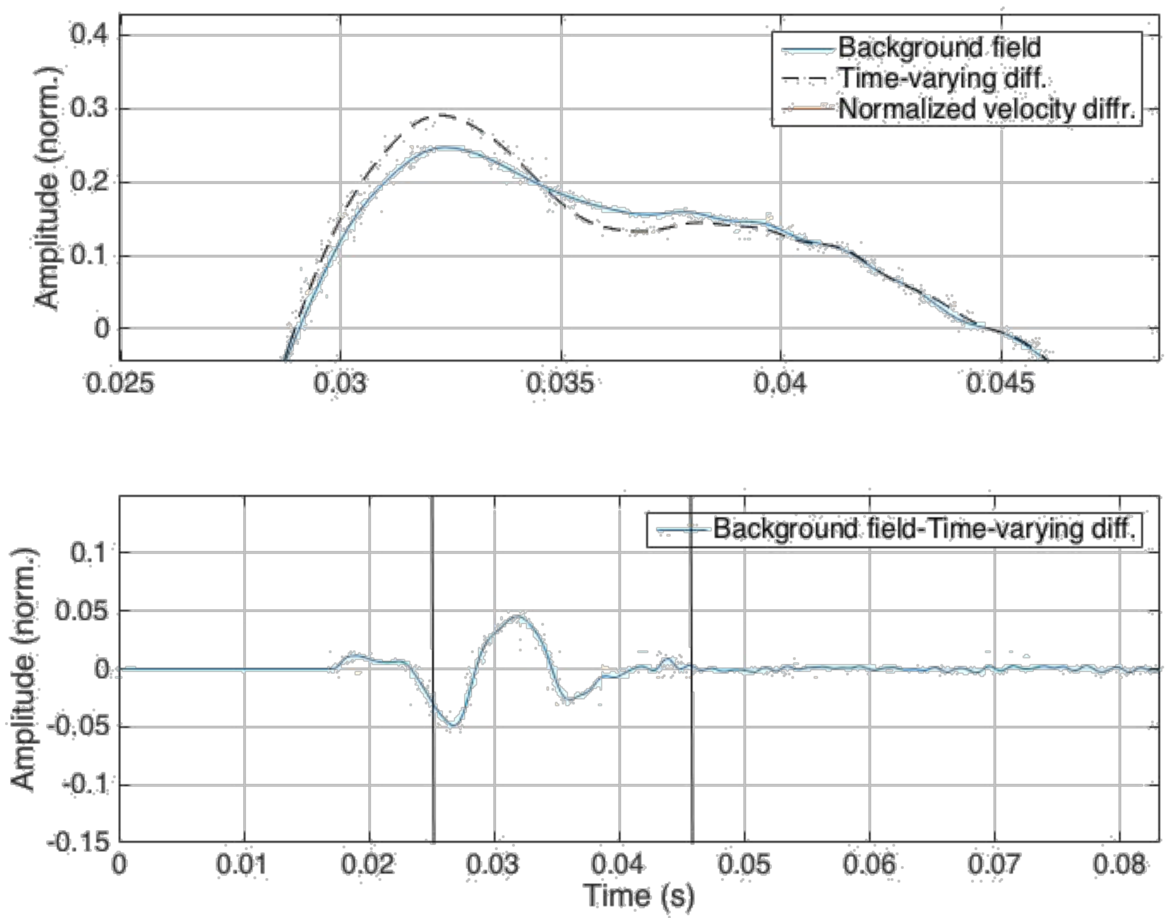


Diffractor: velocity 200 m/s
radius=10 m
time function = gaussian

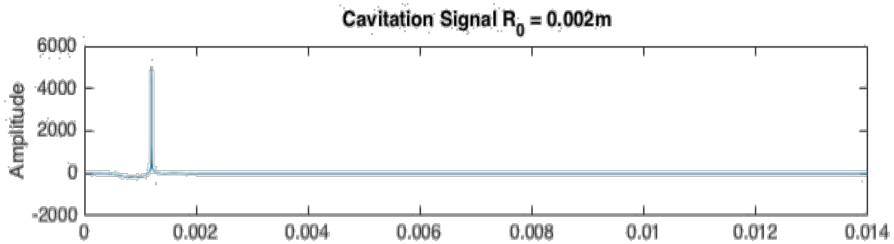
Trace 20 m below diffractor

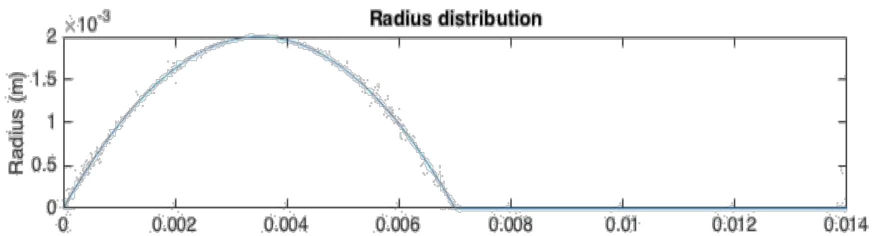


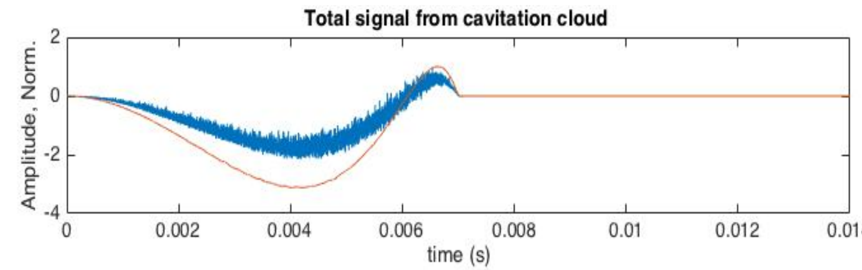
Trace 20 m below diffractor

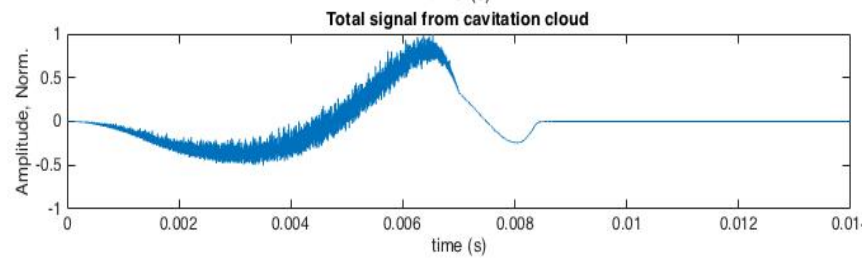


Collapse of cavity cloud





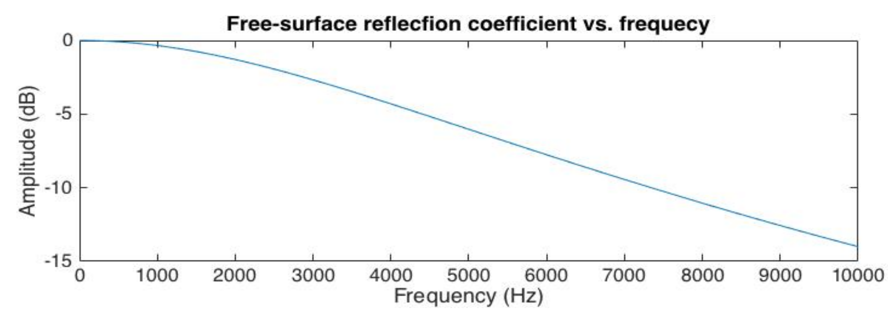




$$n(t) = n_0\left(1 - \frac{(t - t_0)^2}{t_0^2}\right), \quad \text{for } 0 < t < 2t_0,$$

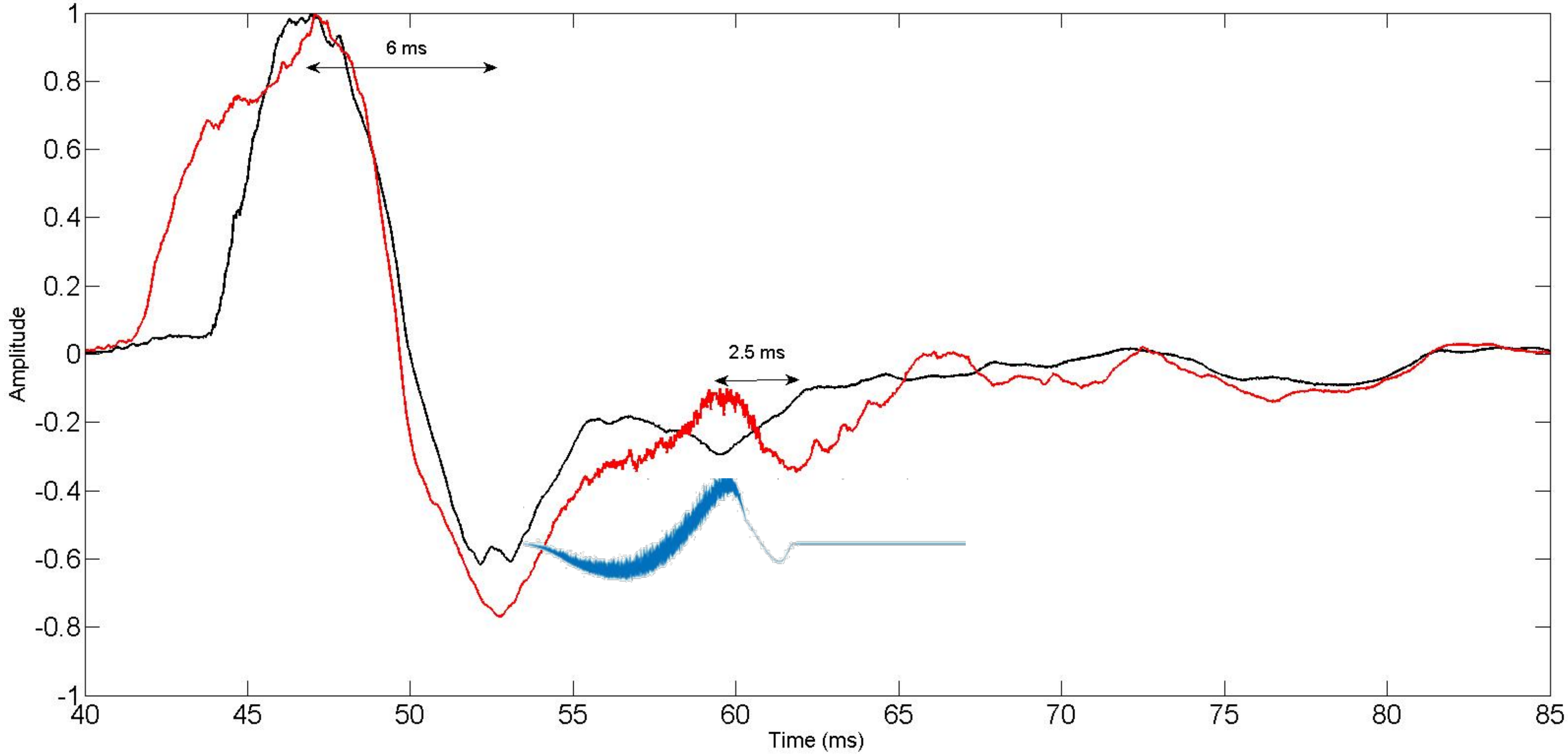
$$R(t) = R_0\left(1 - \frac{(t - t_0)^2}{t_0^2}\right), \quad \text{for } 0 < t < 2t_0.$$

$$T = 0.915R\sqrt{\frac{\rho}{p_h}} \qquad s_2(t) = \frac{1}{r}s_1(rt)$$



Landrø et al. (2016)

Comparison with data



Conclusions

- Ghost cavitation is an indication that the medium is time-varying => non-linear wave equation
- Conventional air gun modeling does not capture this non-linearity => differences between modeled and measured source signatures
- Simple attempts to model the ghost cavitation process indicate potential for improved air gun modeling
- Diffractor model does not fit the observed data
- Sum of cavitation collapse more promesing model.

References

- Landrø, M., Y. Ni and L. Amundsen (2016) Reducing high-frequency ghost cavitation signals from marine air gun arrays. Geophysics, Vol.81, No.3