



**HAL**  
open science

## Identification of acoustic moving sources in the context of a road vehicle at pass-by: A numerical comparison

Rémi Cousson, Marie-Agnès Pallas, Quentin Leclère, Michel Bérengier

### ► To cite this version:

Rémi Cousson, Marie-Agnès Pallas, Quentin Leclère, Michel Bérengier. Identification of acoustic moving sources in the context of a road vehicle at pass-by: A numerical comparison. Forum Acusticum, Jun 2017, BOSTON, United States. Acoustical Society of America, Forum Acusticum, 5 (141), pp.3883, 2017, 10.1121/1.4988696 . hal-01627750

**HAL Id: hal-01627750**

**<https://hal.science/hal-01627750>**

Submitted on 13 Nov 2017

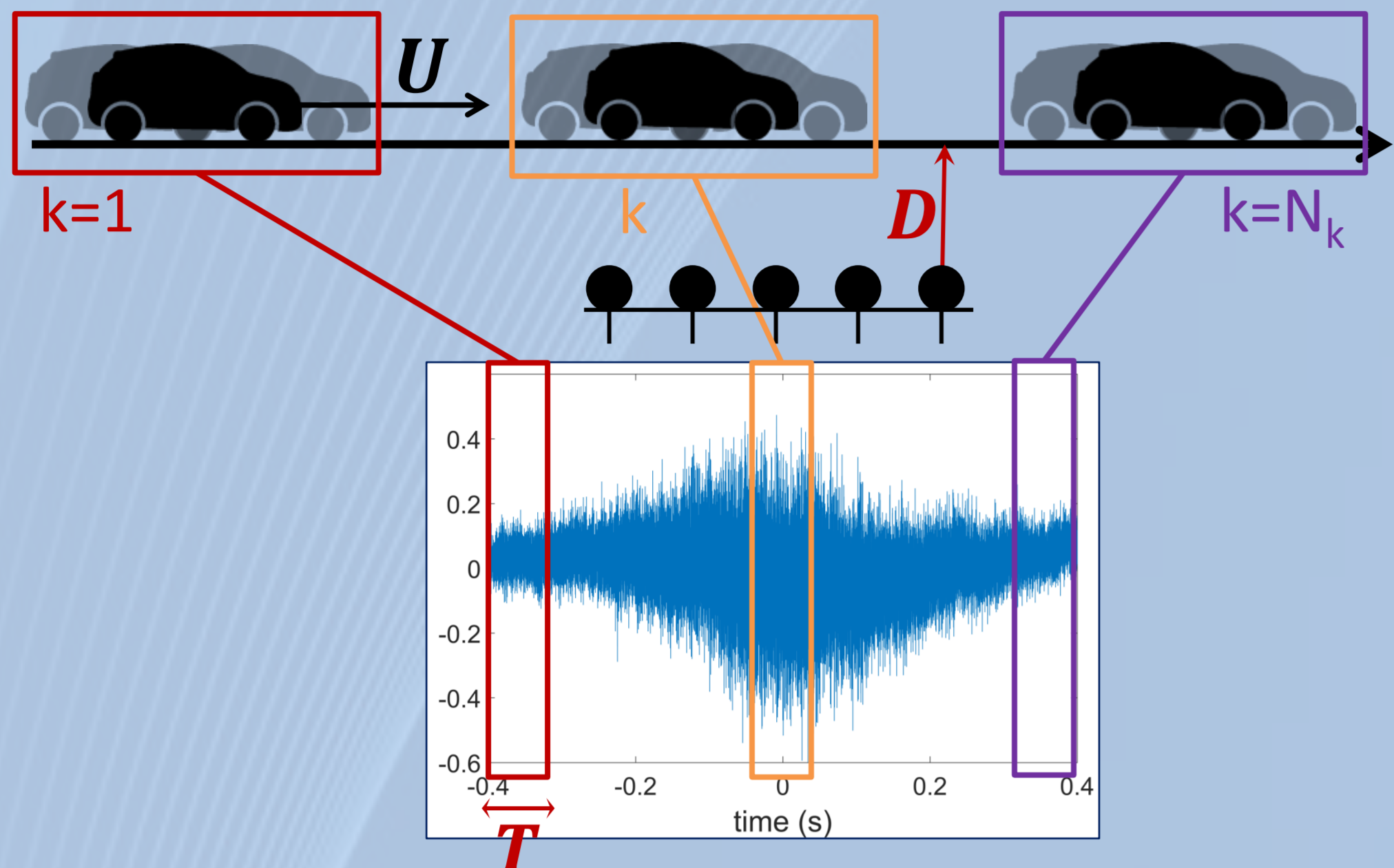
**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



# Identification of acoustic moving sources in the context of a road vehicle at pass-by: a numerical and experimental comparison

## METHOD DESCRIPTION: MOVING SOURCE ADAPTED - PSF



Assumptions:

- Uncorrelated sources
- Monopoles linearly moving at constant speed  $U$
- $UT \ll D$
- Ergodic random sources
- Differences in dopplerized frequencies  $< \Delta f (= \frac{1}{T})$

Snapshot  $k$  ( $k=1..N_k$ ):

$$\text{Beamforming at frequency } f_{dopp}^{(k)} = \frac{f}{1 - M \cos \theta_k}$$

$$\text{PSF calculated at } f_{dopp}^{(k)}$$

- Averaged BF output over  $N_k$
- Averaged PSF over  $N_k$
- Deconvolution

$$\tilde{H}(\omega_p) \mathbf{s}(\omega_p) = \mathbf{b}(\omega_p)$$

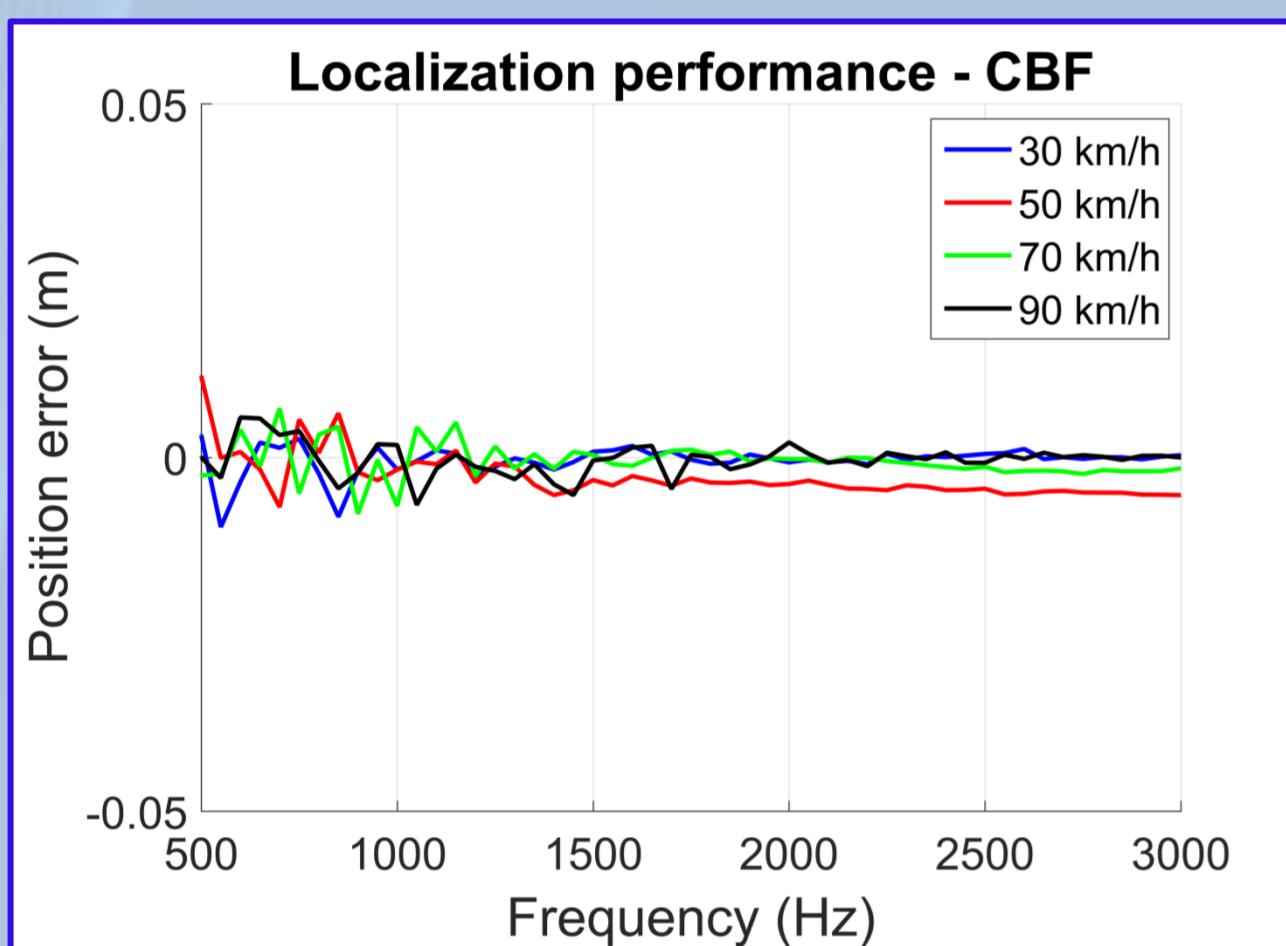
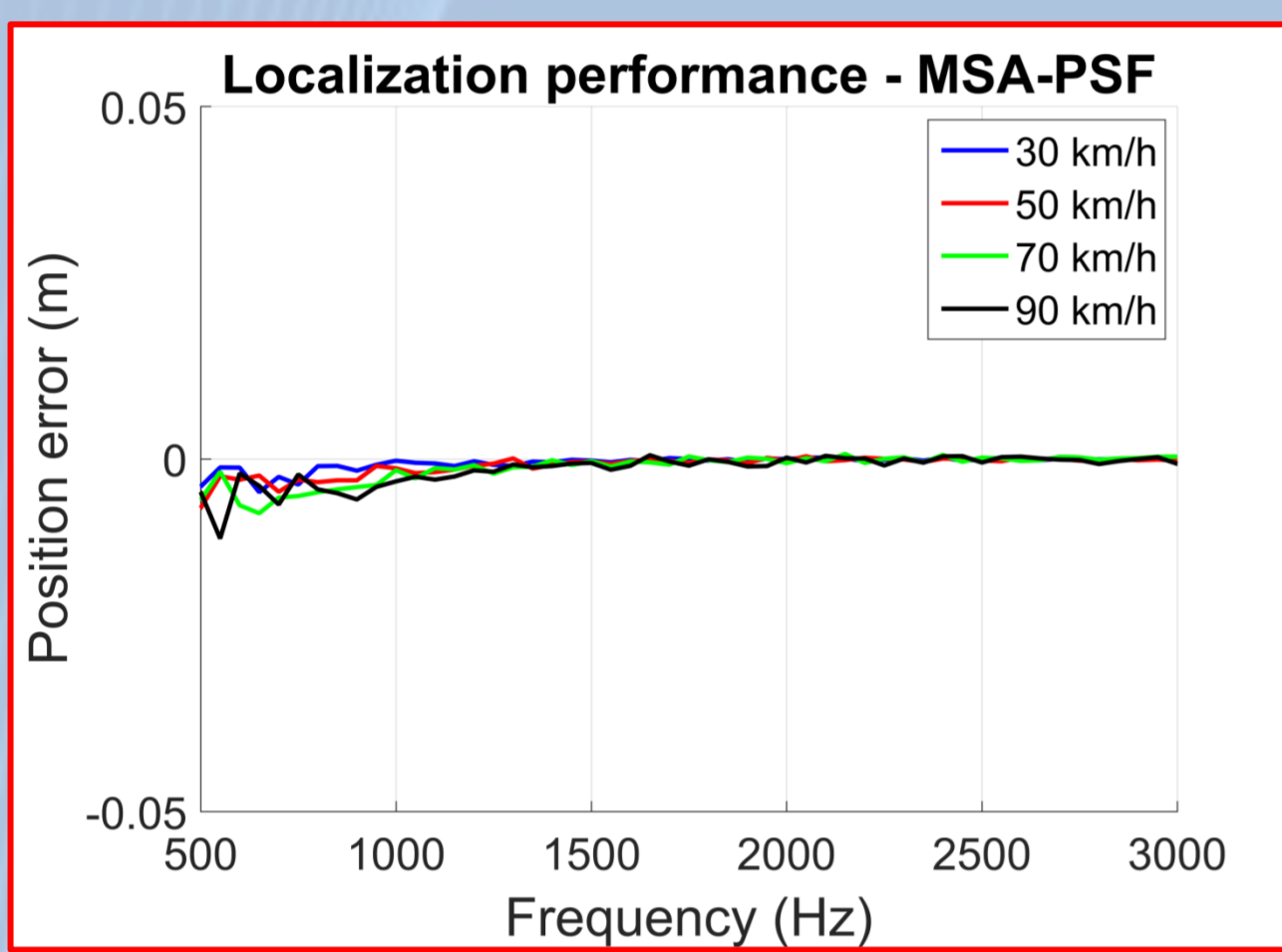
$$b_i(\omega_p) \approx \sum_{m,n=1}^{N_M} \tilde{G}_{i,m}^* \left( \frac{\omega_p}{1 - M_{i,m}^{(k)}} \right) \Gamma_{i,m,n}^{(k)}(\omega_p) \tilde{G}_{i,n} \left( \frac{\omega_p}{1 - M_{i,n}^{(k)}} \right)$$

$$\tilde{H}_{i,j}(\omega_p) = \left| \sum_{m=1}^{N_M} \tilde{G}_{i,m}^* \left( \frac{\omega_p}{1 - M_{i,m}^{(k)}} \right) \tilde{G}_{j,m} \left( \frac{\omega_p}{1 - M_{i,m}^{(k)}} \right) \right|^2$$

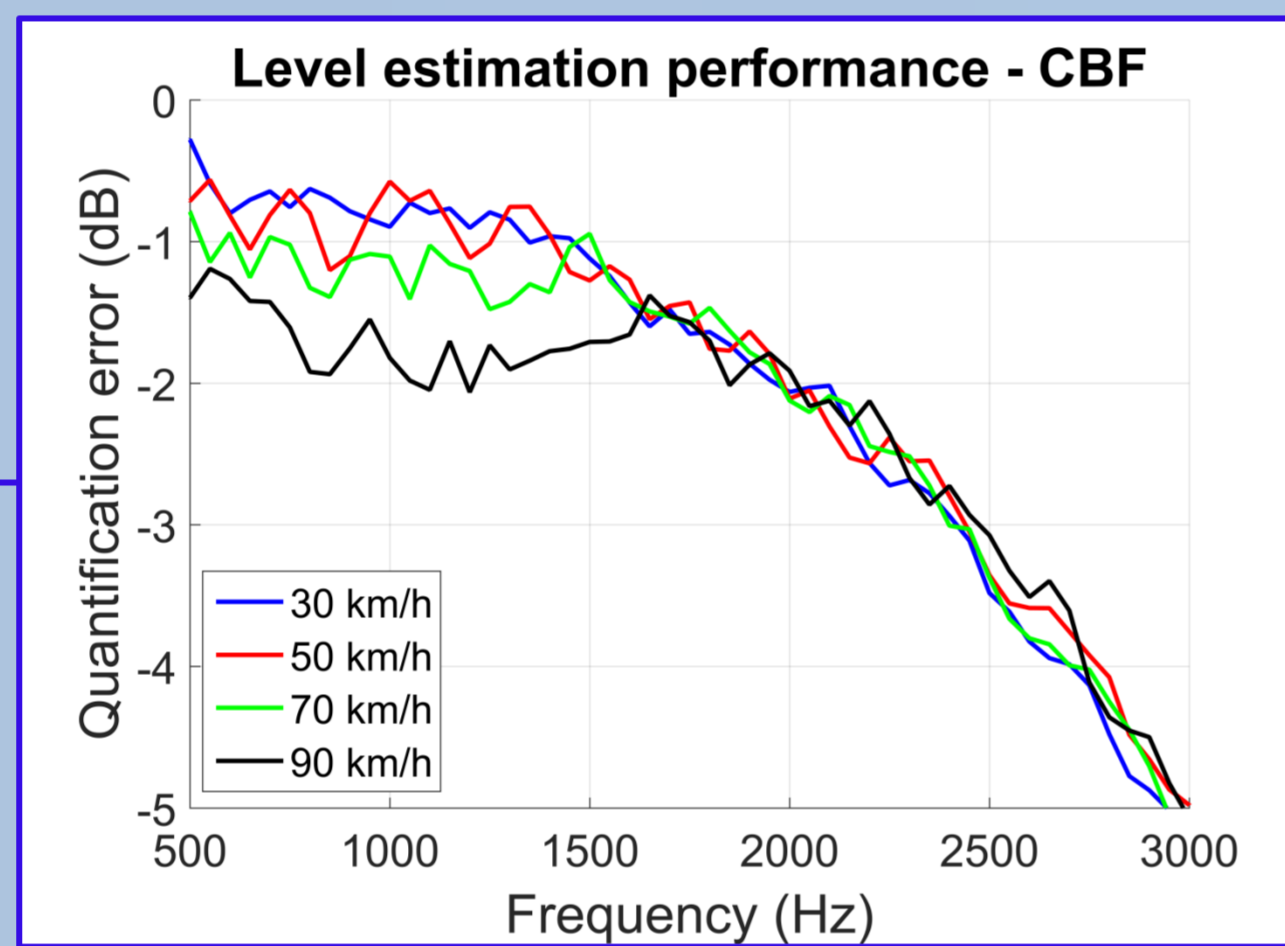
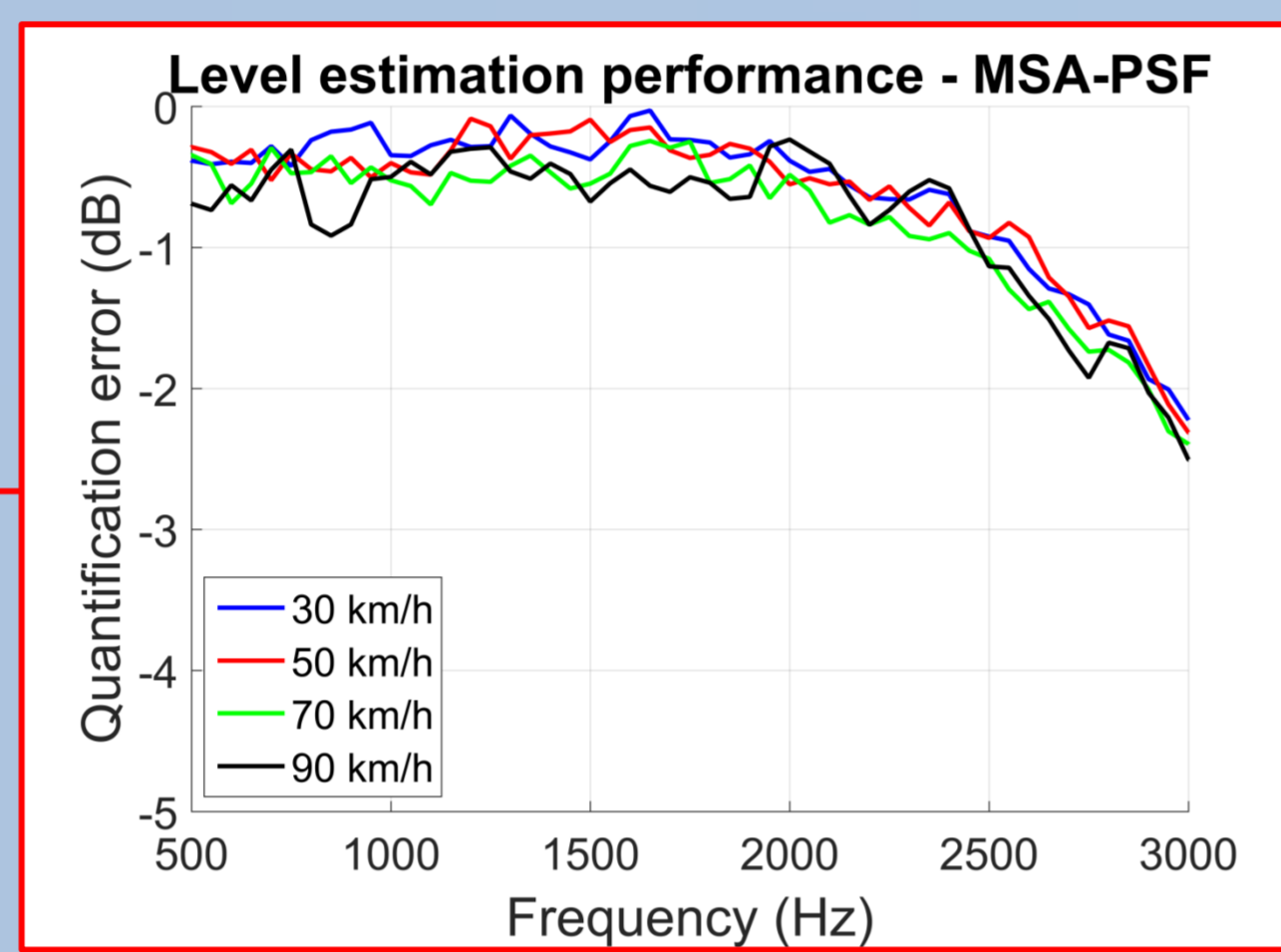
$$\Gamma_{i,m,n}^{(k)}(\omega_p) = \tilde{P}_m^{(k)} \left( \frac{\omega_p}{1 - M_{i,m}^{(k)}} \right) \tilde{P}_n^{(k)*} \left( \frac{\omega_p}{1 - M_{i,n}^{(k)}} \right)$$

## NUMERICAL SIMULATIONS: PERFORMANCE ASSESSMENT

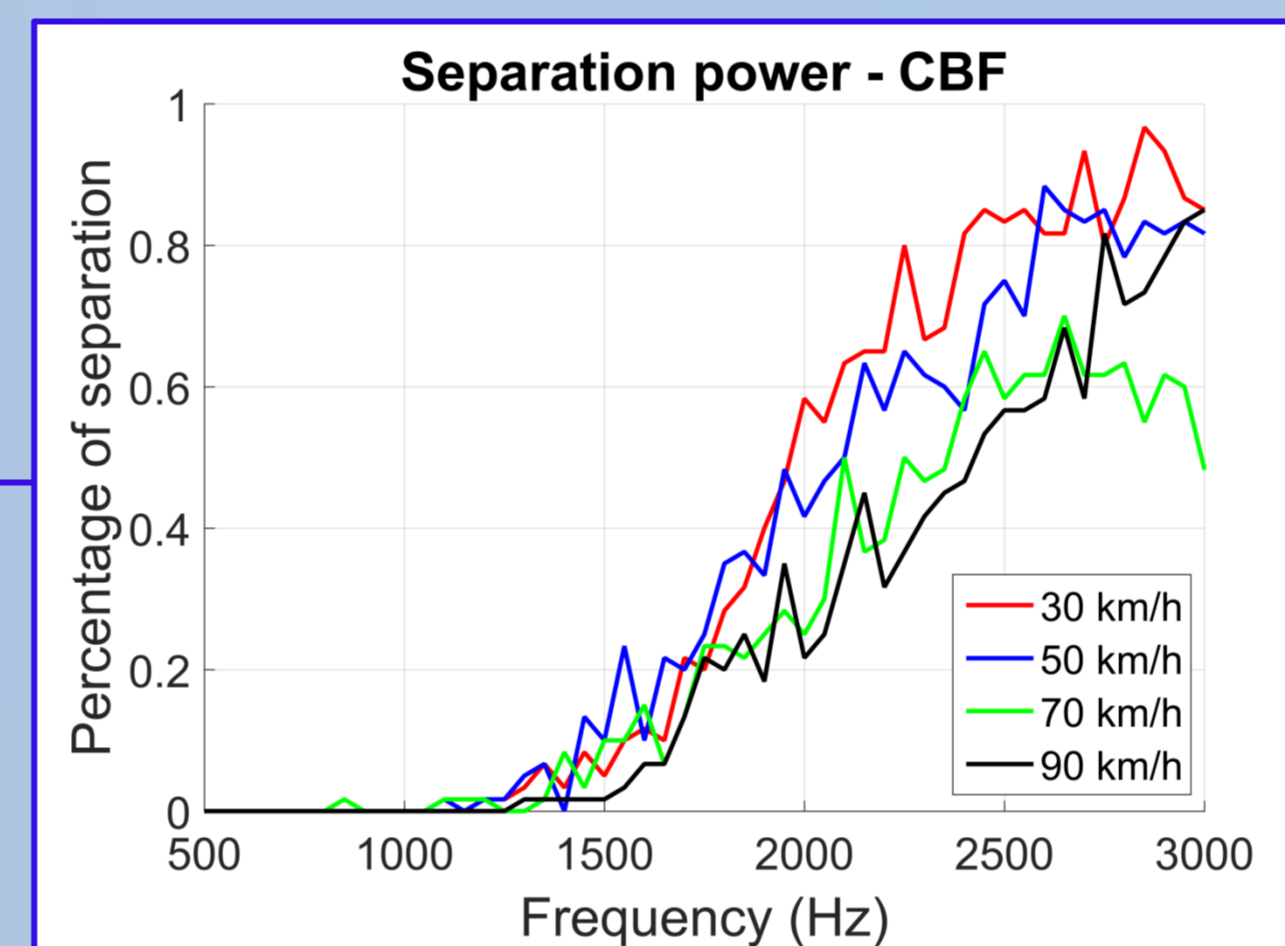
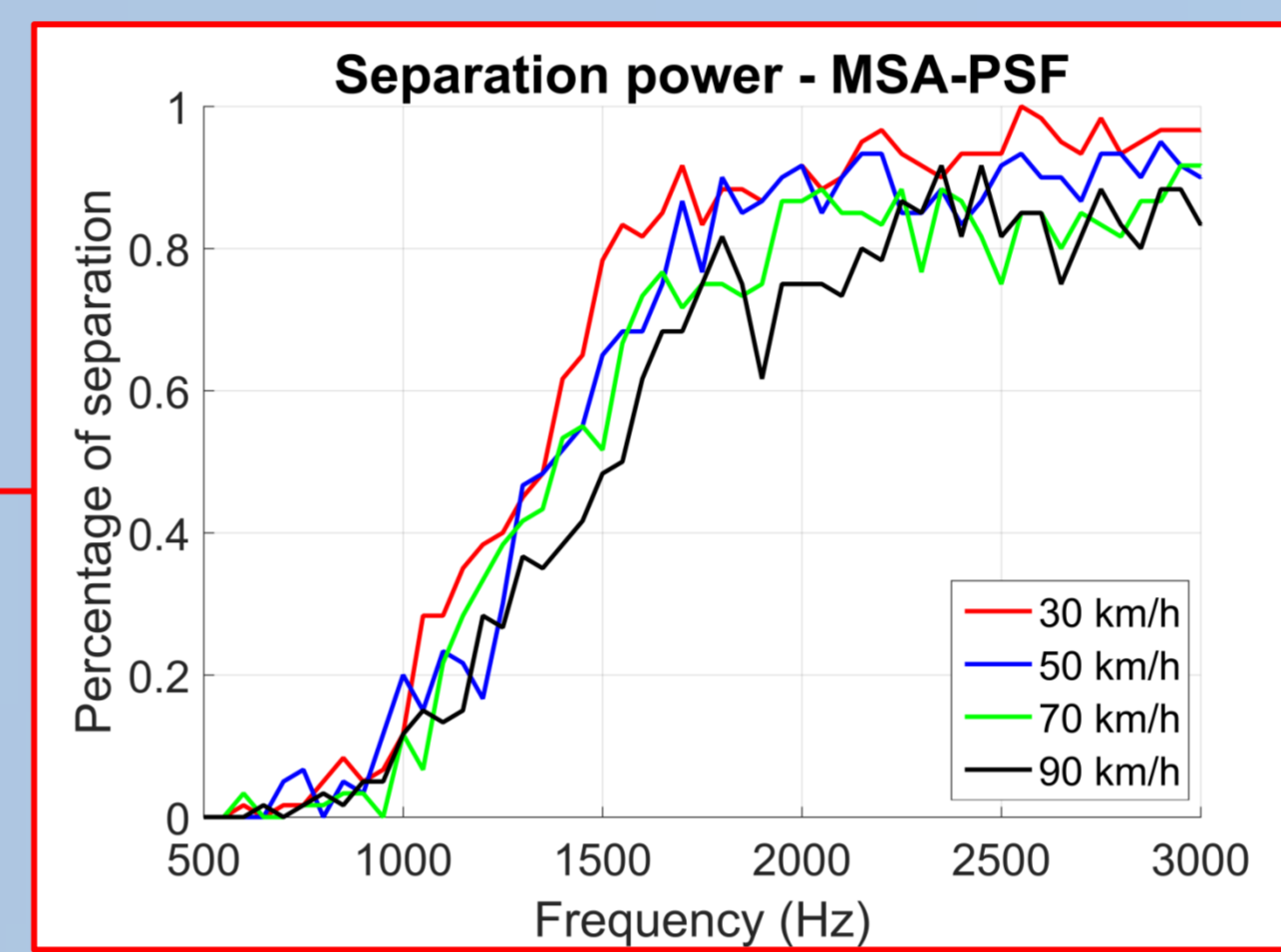
### 1. LOCALIZATION



### 2. QUANTIFICATION



### 3. SEPARATION POWER



### SIMULATION PARAMETERS

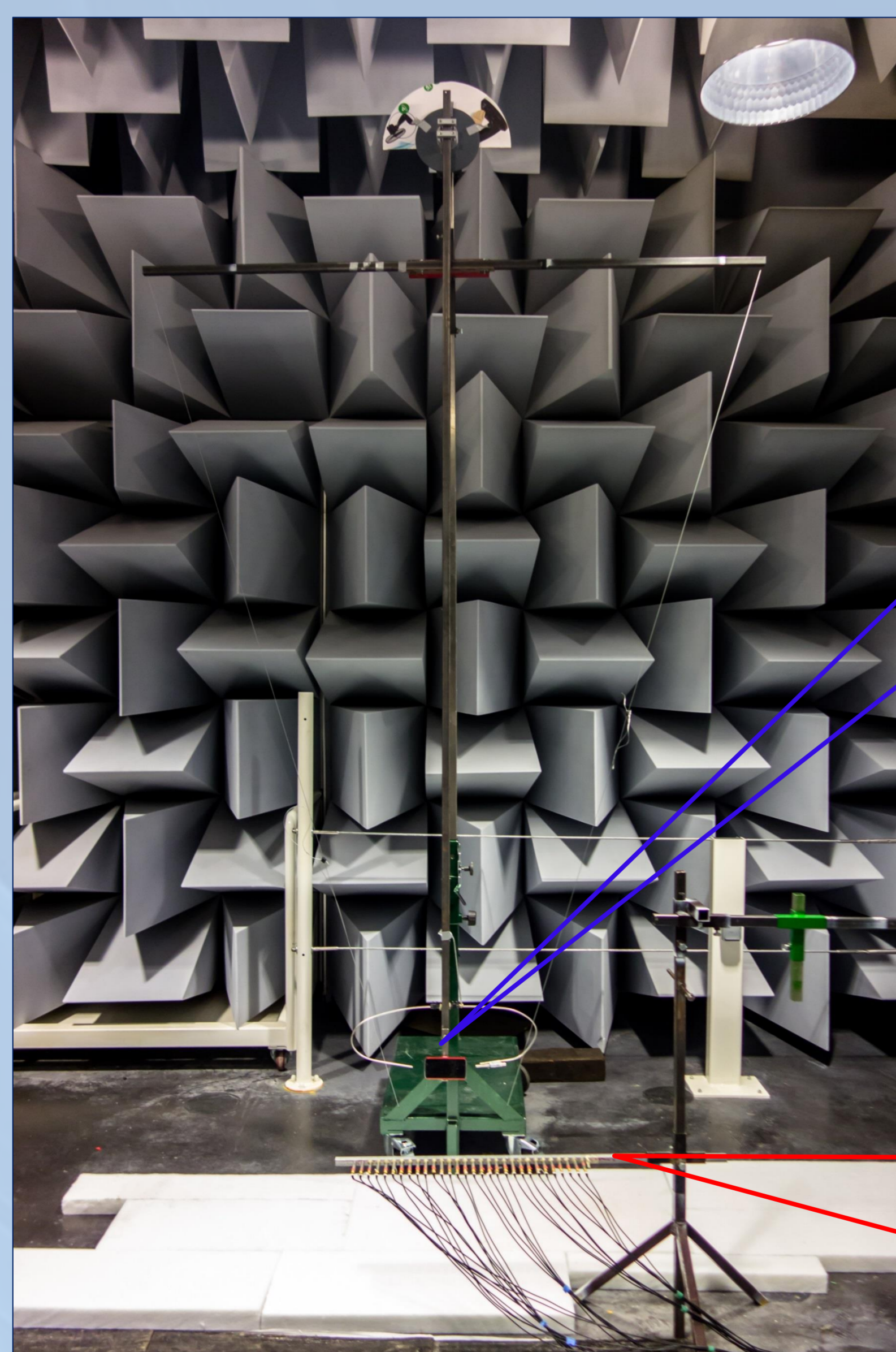
$F_s = 8000$ Hz	$X_{\text{source}} = 0$ m
$N_M = 32$ sensors	$X_{\text{sep}} = [-0.05; +0.05]$ m
$d = [0.05 - 0.29]$ m	$f_{\text{range}} = [500 - 3000]$ Hz
$L_{\text{array}} = 4$ m	$T = 0.02$ s
$D = 4$ m	$N_k = 29$
$T_{\text{signal}} = 2$ s	Overlap = 60%
$U = [30 - 90]$ km/h	$N_{\text{simus}} = 60$

MSA-PSF: Moving Source Adapted - Point Spread Function

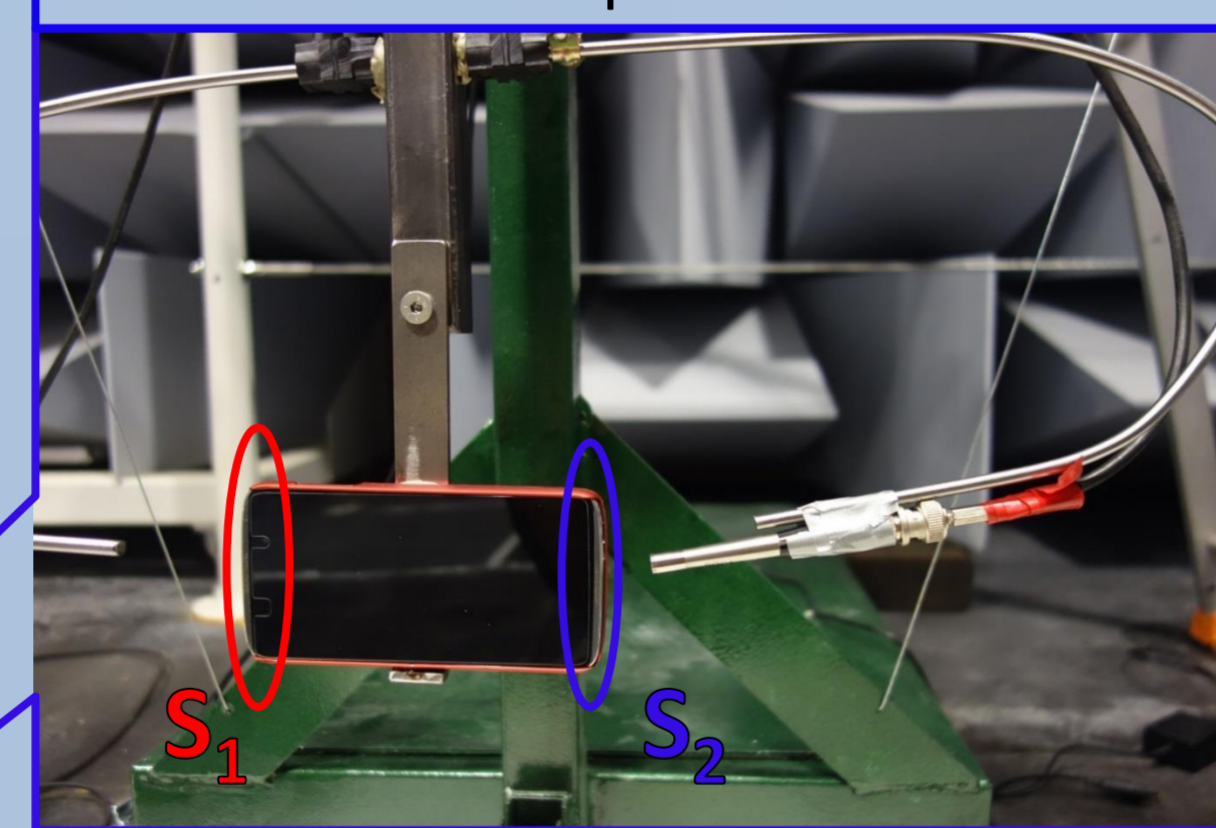
CBF: Conventional Beamforming (Sweeping focus time domain BF + Deconvolution with static PSF)

- Better localization of sources: more robust and less dispersive
- Better quantification: error  $< 1$  dB until 2.5 kHz vs error  $> 1$  dB in whole frequency range for CBF
- Better separation of close sources

## ACADEMIC EXPERIMENT



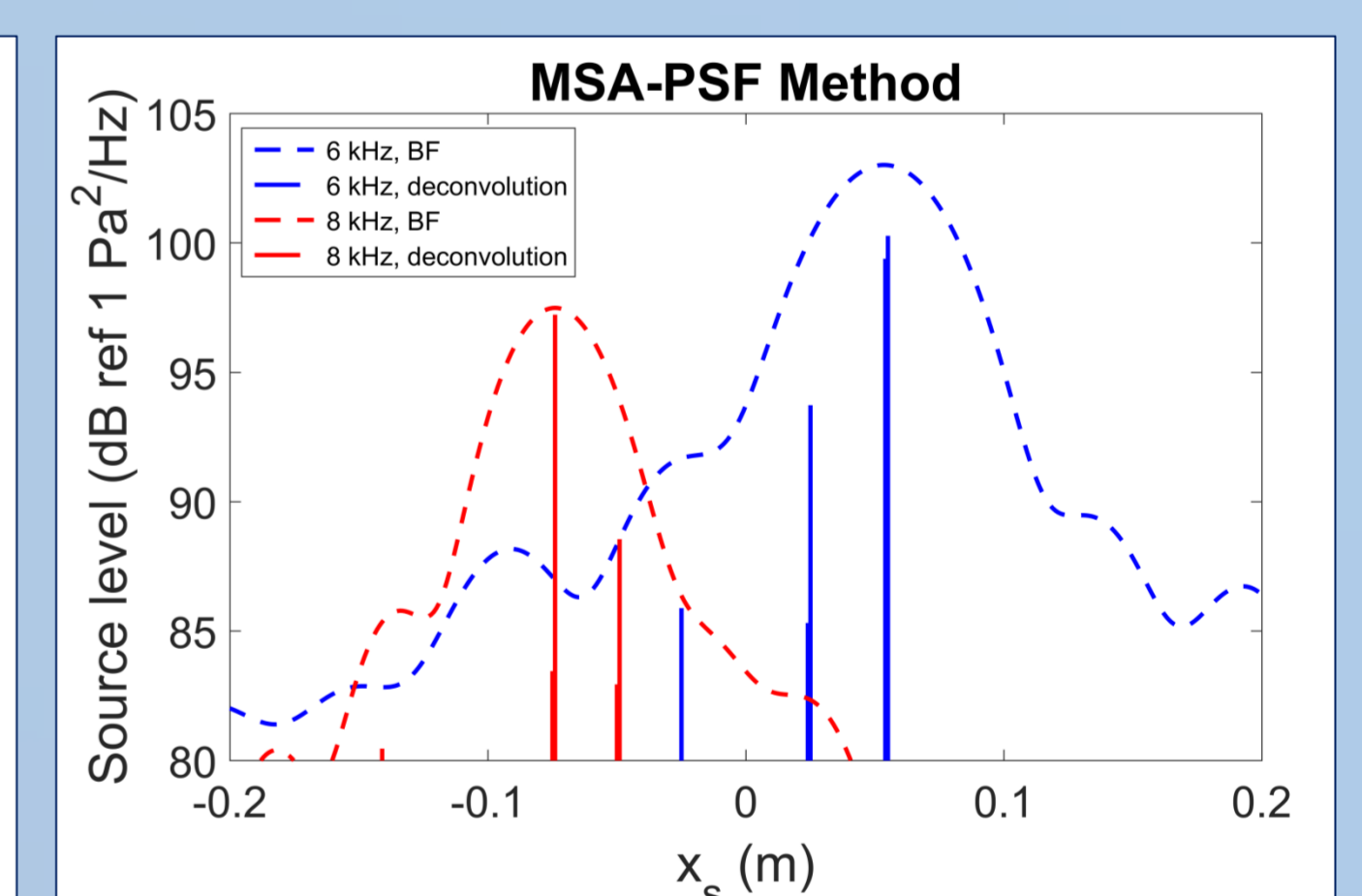
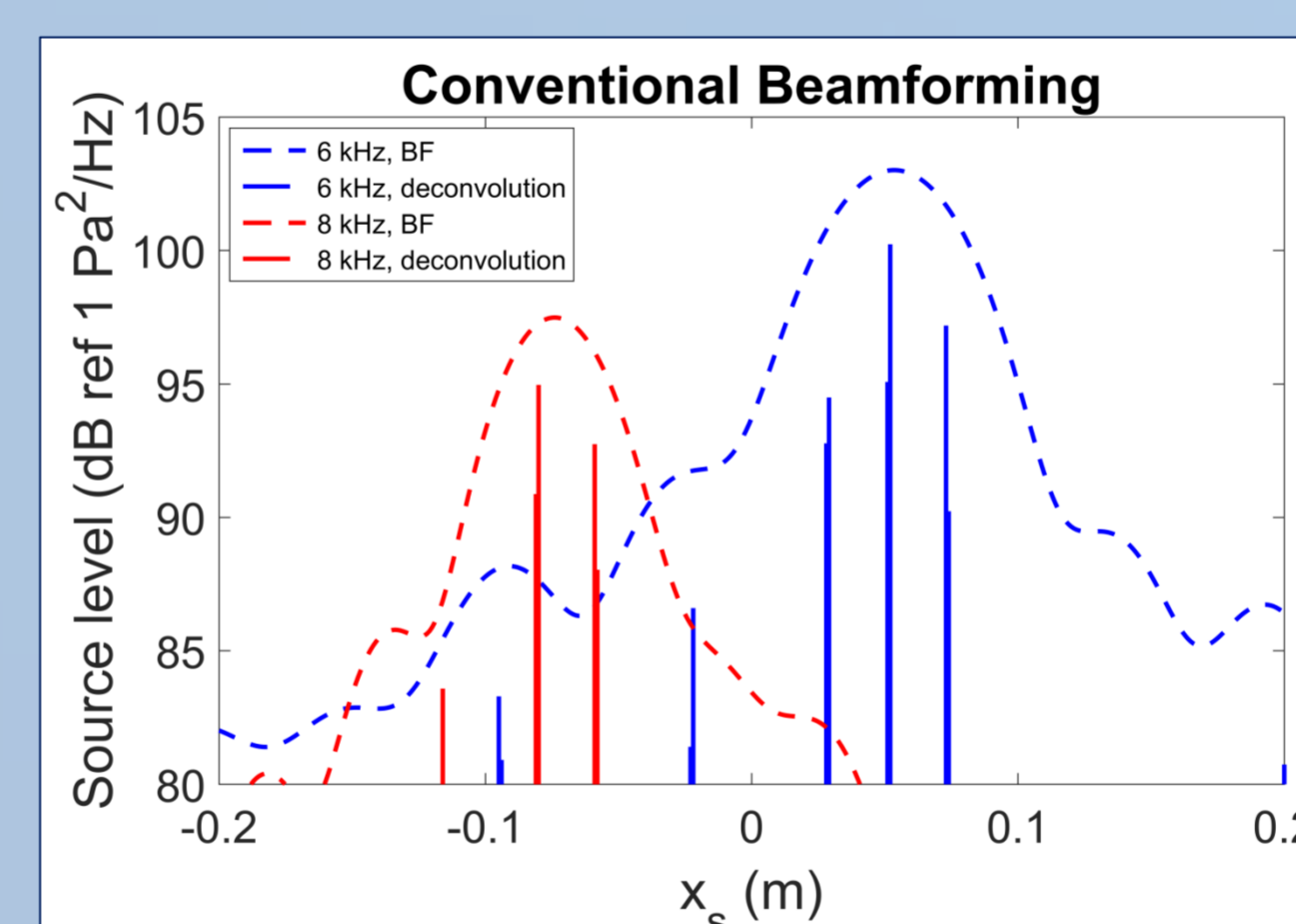
Moving sources: Smartphone with two independent loudspeakers



30 Microphones linear array microphones



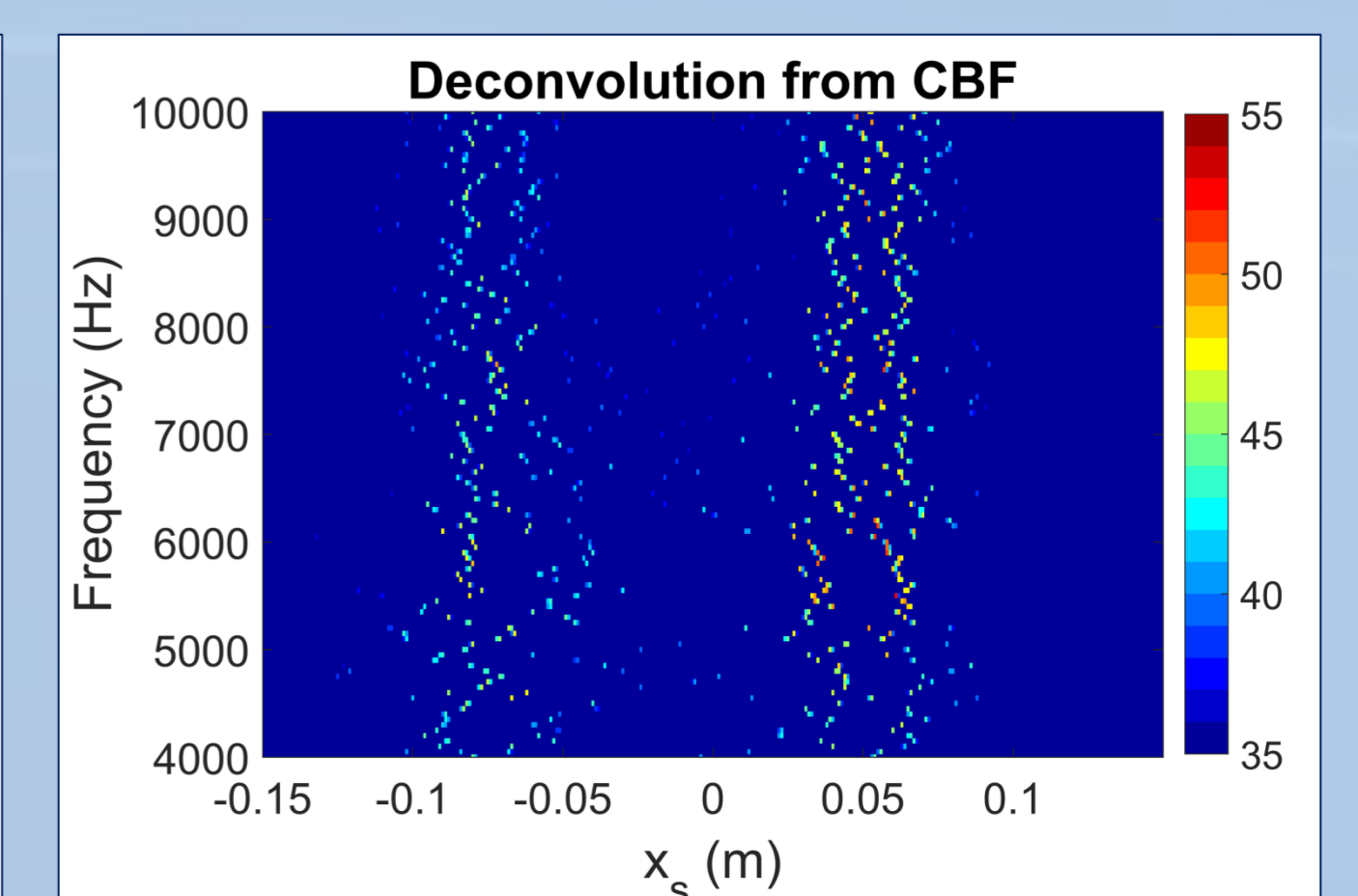
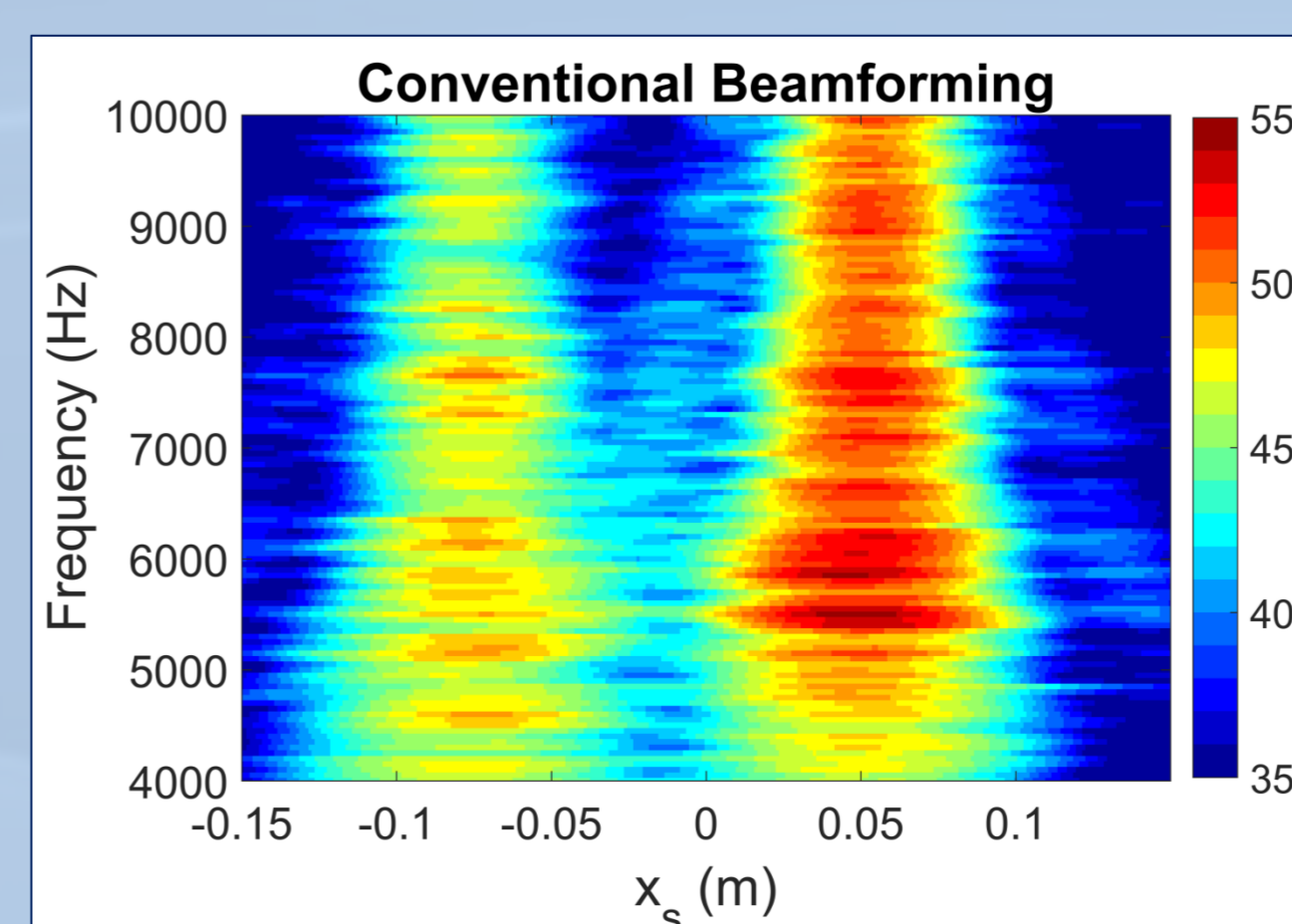
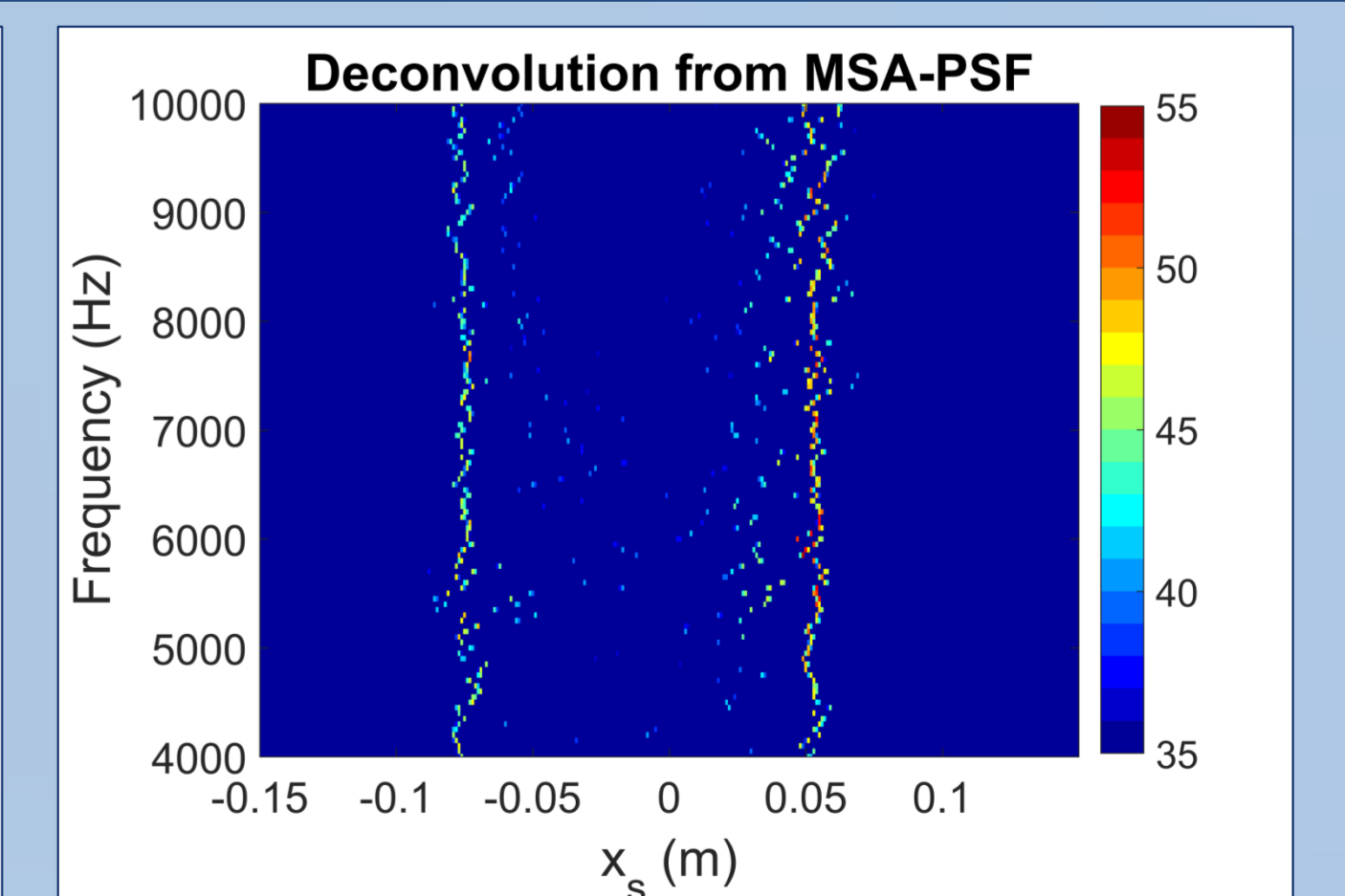
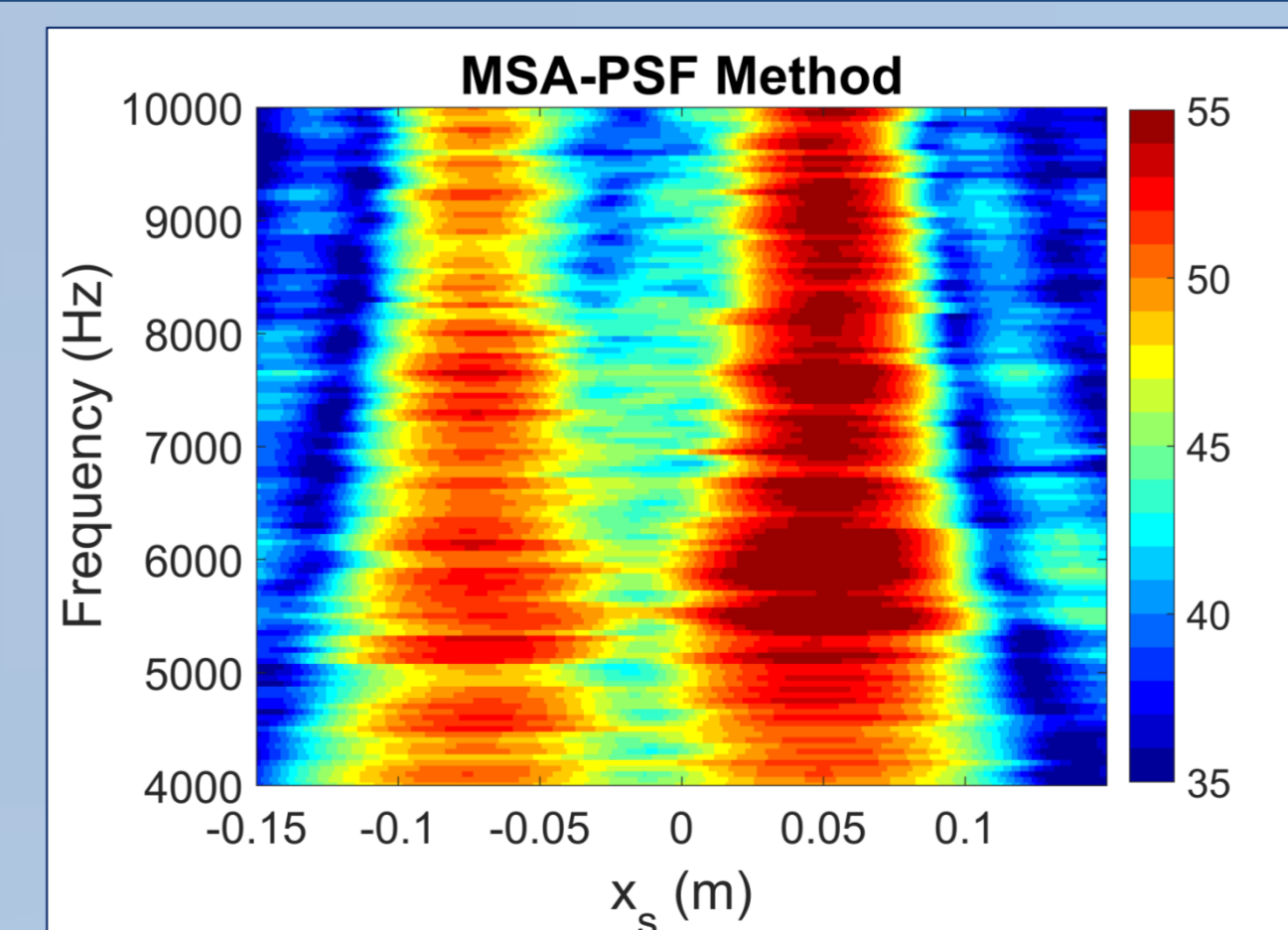
TONE SOURCES



$F_s = 51200$  Hz  
 $P = 30$  sensors  
 $d = 0.02$  m  
 $D = 0.5$  m  
 $T_{\text{signal}} = 2$  s  
 $U = 3.5$  m/s

$X_{\text{sources}} = [-0.06; +0.06]$  m  
 $f_{S1} = 8$  kHz  
 $f_{S2} = 6$  kHz  
 $T = 0.02$  s  
 $N_k = 21$   
 Overlap = 60%

RANDOM NOISES



## REFERENCES

- [1] V. Fleury, J. Bulté, *Extension of deconvolution algorithms for the mapping of moving acoustic sources*, J. Acoust. Soc. Am., Vol. 129, 1417-1428 (2011)
- [2] B. Oudompheng, *Array processing for the localization and the contribution of acoustic sources of passing-by ship using a short antenna*, Univ. Grenoble Alpes (2015)
- [3] P.M. Morse, K.I. Ingard, *Theoretical Acoustics*, Princeton University Press, 717-726 (1992)

## PERSPECTIVES

Real pass-by condition measurements

