Characterization and localization of oil leakages using passive acoustic techniques

Xing Yang, Raviteja Chinnambetib, Lei Cao, The Department of Electrical Engineering, The University of Mississippi
Xudong Fan, Likun Zhang, The Department of Physics & Astronomy, The University of Mississippi
Zhiqu Lu, National Center for Physical Acoustics, The University of Mississippi, University, MS

Introduction

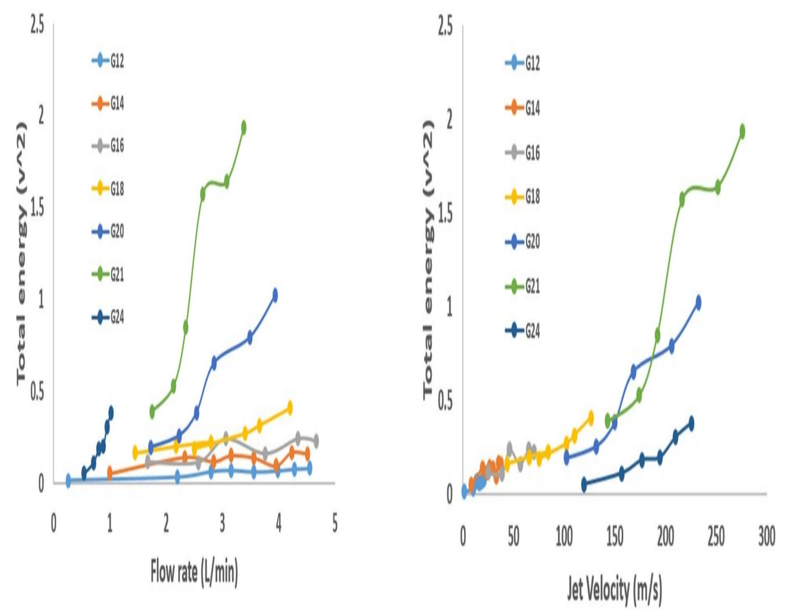
Rapid growth of oil production in the Gulf of Mexico increases the risk of oil spills. A monitoring system is essential to improve safety and reduce the risk of environmental damage. The leaked oil creates underwater sounds and can be recorded by acoustic sensors (hydrophones). This project is focus on developing a hydrophone network-based real-time passive monitoring system for detecting, locating, and characterizing hydrocarbon leakages undersea.

The tasks of the research are:

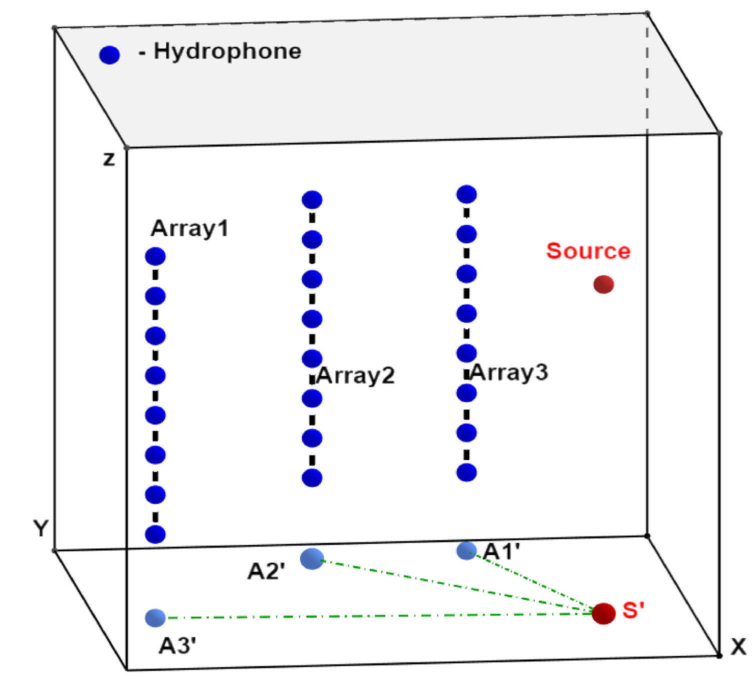
1. Conduct a laboratory study to simulate hydrocarbon leakage under controlled conditions (pressures, flow rates, opening sizes, and types of leakages), to record the oil leakage-induced underwater sound, and to establish the correlation between frequency spectra and oil leakage properties, such as oil-jet intensities and speeds, bubble radii and distributions, and crack sizes.
2. Implement and develop acoustic bubble modeling for estimating features and strength of the oil leakage
3. Develop a set of signal processing and triangulation algorithms for leakage identification and localization.

Picture of constant flow bubbles

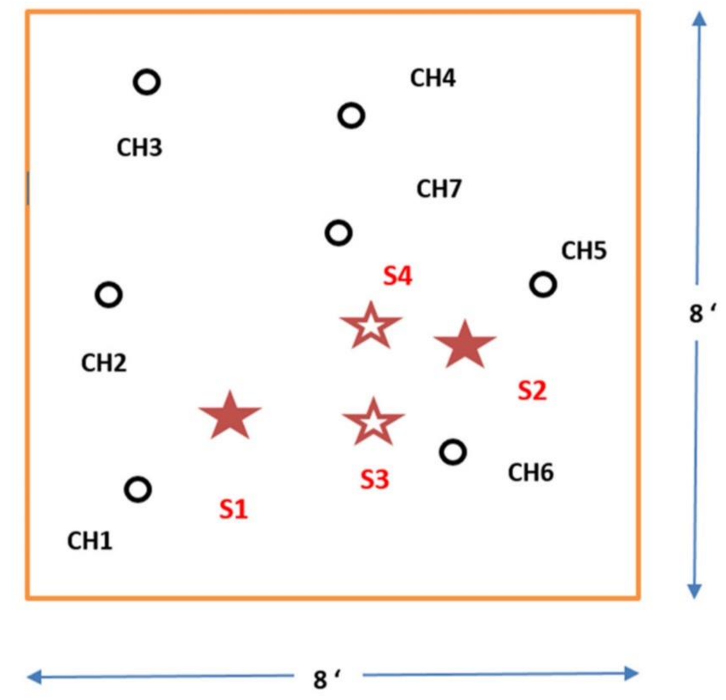
Total energy vs flow rate and jet velocity



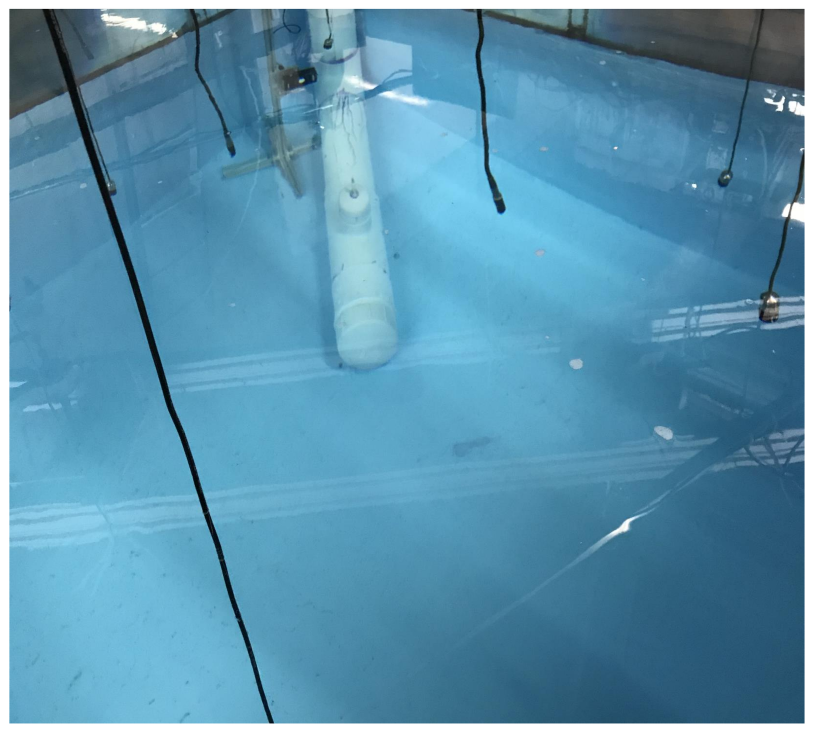
Front view of hydrophone array and sources



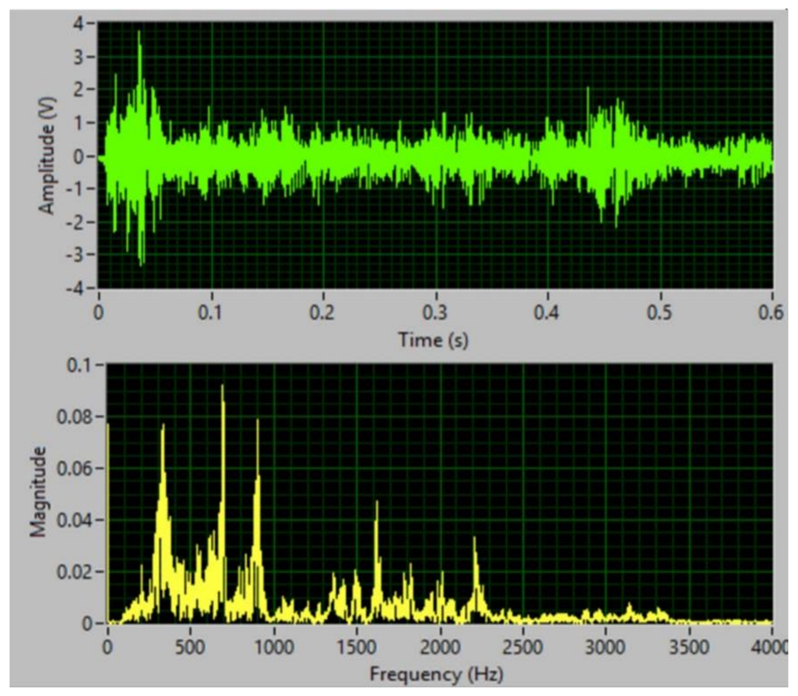
Top view of hydrophone network and sources



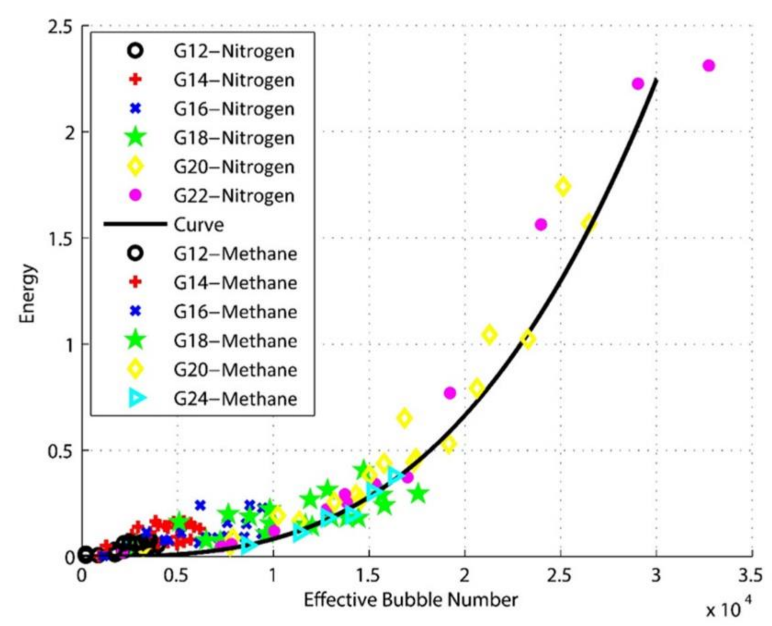
Experimental Setup



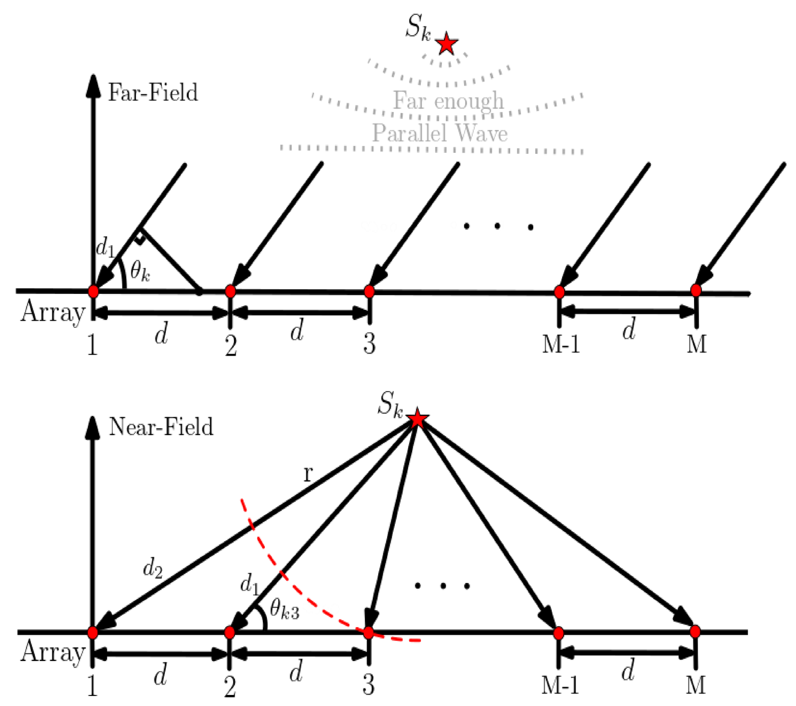
Signals from constant flow bubbles



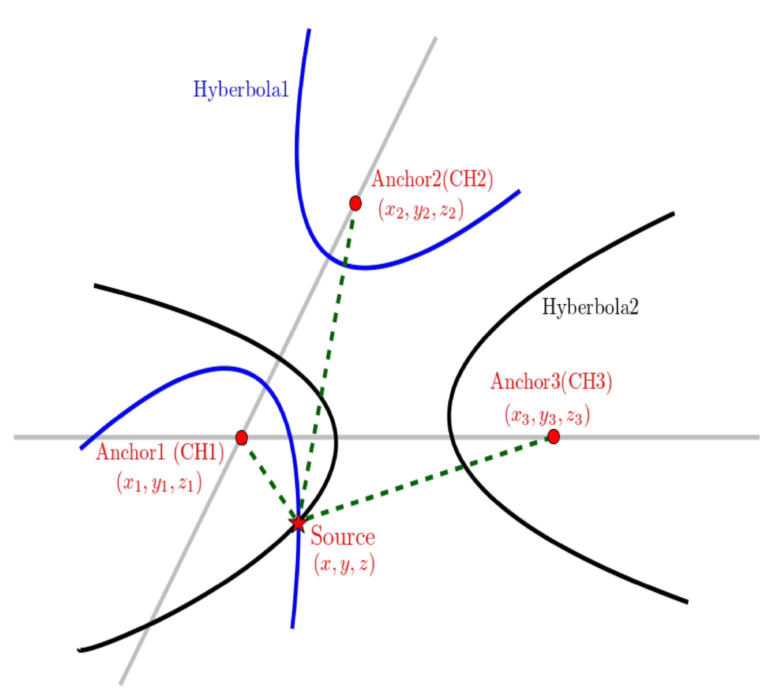
Total energy vs effective bubble number



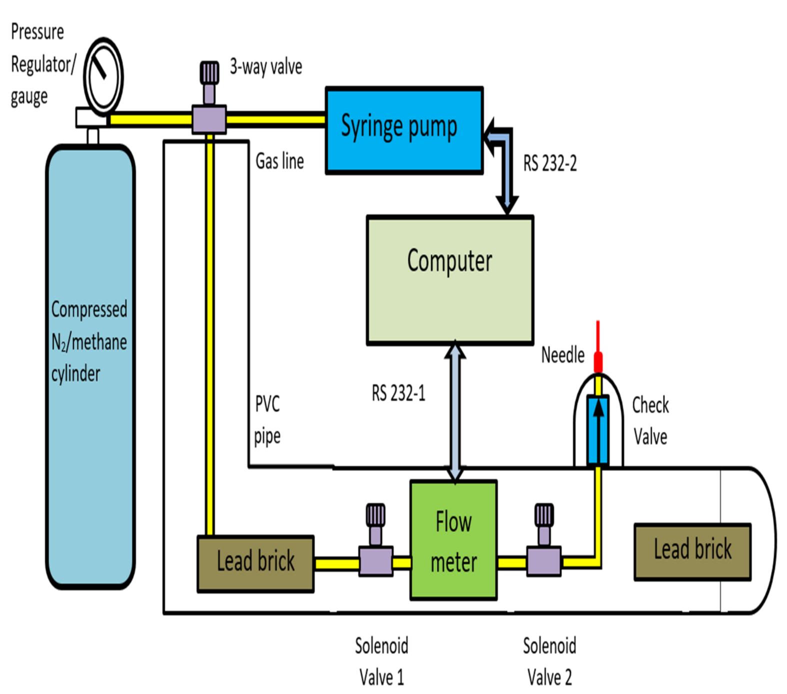
DOA-based localization concept



TDOA-based localization concept

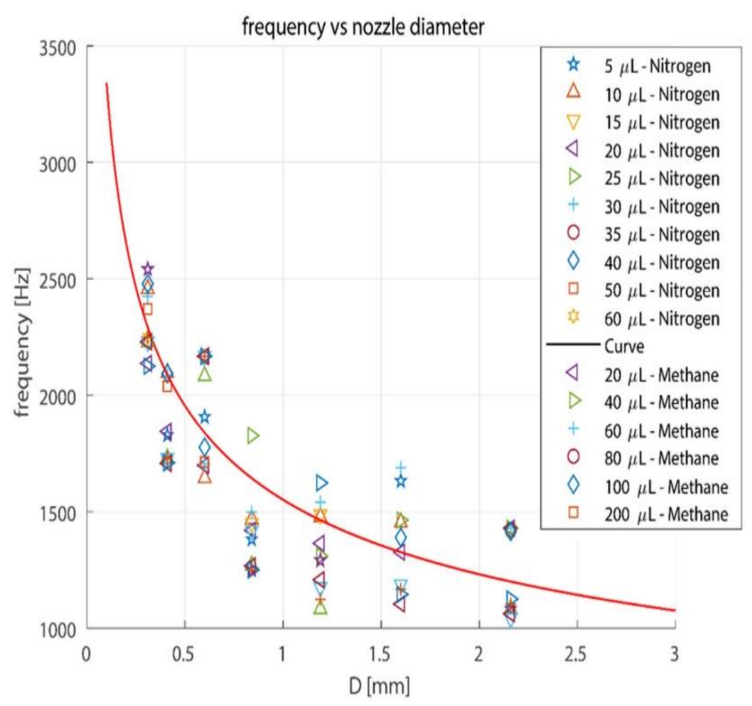


Bubble generation



Picture of a few bubbles

Resonant frequency vs nozzle diameter



Results of DOA-based localization

Method	First of Arrival Estimation Error Range	RMSE
TDOA (s)	(2.55E-07 , 7.51E-06)	3.14E-06
3Dfrom2D(°)	(0.18 , 5.47)	2.734

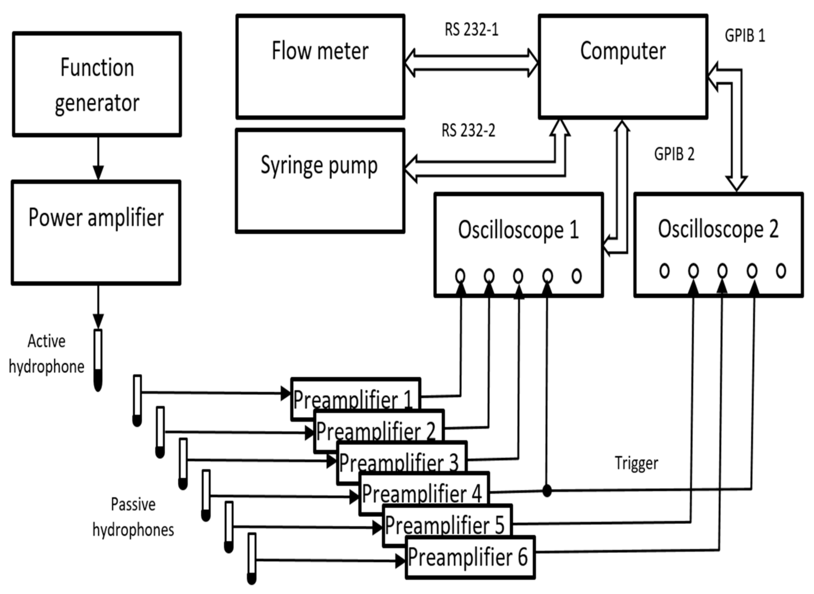
Source (cm)	True Location
	(170,74,126)

Method	Estimated Location	RMSE
LSE (cm)	(185.48,63.15,125.3)	10.92
TSE (cm)	(190.85,62.32,129.23)	13.92
3Dfrom2D (cm)	(155.83,68.84,121.71)	5.54

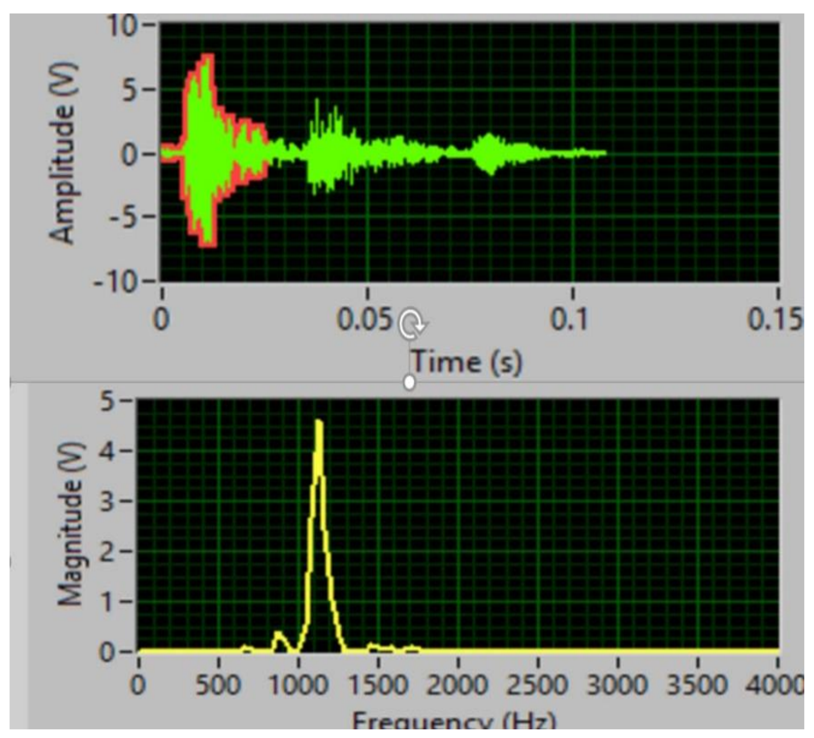
Results of TDOA-based localization

Source	True Location (cm)	Estimated Location (cm)		RMSE (cm)	
		LSE	TSE	LSE	TSE
S1	(174.0,73.0,136.0)	(180.6,75.8,134.8)	(179.6,76.7,135.6)	4.20	3.88
S2	(90.0,64.0,115.0)	(90.6,65.1,105.5)	(90.3,65.3,107.0)	5.53	4.68
S3	(139.5,52.5,145.0)	(138.4,52.4,151.1)	(136.9,53.1,144.0)	3.58	1.65
S4	(136.0,112.5,140)	(133.4,115.5,146.2)	(136.3,115.6,145.6)	4.25	3.70

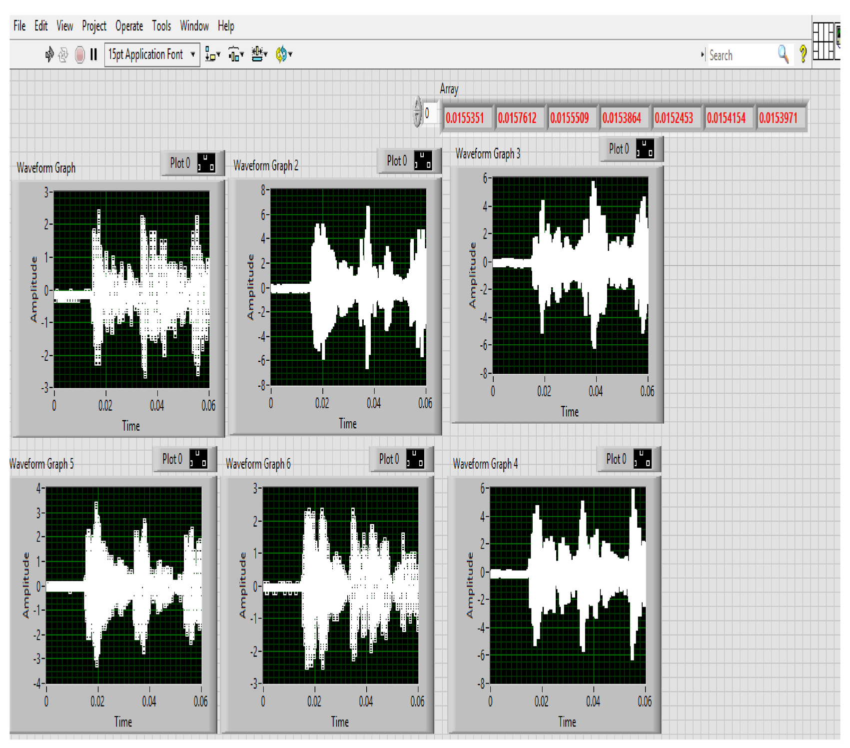
Data Acquisition



Signals from a few bubbles



Signals from the bubbles



Swimming pool test

Conclusions

- Acoustic signatures in terms of total energy and resonate frequency can be used to estimate the intensity and crack size of oil leakages
- Localization algorithms were able to determine the locations of bubble sources

Acknowledgment

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