ABSTRACTS

Due to the recent blowout disasters that resulted in huge loss of lives, environmental damages, as well as large payouts, there is increasing pressure from the industries and the regulators to ensure the safe operation of the wellbore. Well-barriers installed to encapsulate the wellbore are designed to protect and prevent leakage. However, over time, due to the constant exposure to hydrocarbon, the well-integrity of the barriers and wellbore may be eroded and compromised. A leakage escaping through the eroded or compromised barrier will generate acoustic radiation that carries a huge amount of information that can be extracted by signal processing. This thesis presents a systematic study of the processing of acoustic radiation to address the complex practical challenges involved in the acoustic signal processing with application in the passive well-integrity monitoring system.

The conventional approach to passive well-integrity evaluation is to deploy single or multiple independent sensors to detect the possibility of breaches or leakages within the wellbore. Even though these approaches have been successful in detecting the leakages, they do not provide other crucial information. Information such as directions, radial locations, and or type of leakages presents in the wellbore are all useful parameters that provide better diagnostics of the wellbore's condition. Recently, the array processing approach was proposed to provide an additional dimension of information to localize the source.

At the beginning of the thesis, conventional array processing algorithms are studied to investigate the advantages of using array in passive well-integrity evaluation. Even though array can provide localization, the array spatial aliasing frequency limits the type of passive source that they can localize. The array spatial aliasing frequency is usually smaller than the typical time-

domain spatial aliasing limit, which is half the sampling rate. This limitation reduces the operating frequency of an array to be below the conventional single or multiple independent sensor approach.

Accordingly, first, the far-field sources are investigated. If the wideband source satisfies a certain condition, an aliasing-free direction-of-arrival is found to be possible through sparse beamforming. However, it is not applicable to the recently proposed grid-free compressing beamforming as it was derived for sources with a single frequency. To alleviate this deficiency, the multiband grid-free technique is proposed. Through the theoretical investigation of a multiband grid-free model, a new cost function for a multiband source that can be solved though semi-definite programming (SDP) is presented. This generalizes the original single band grid-free to a multiband representation. This is validated with simulation and experimental test result.

Next, the study moved to near-field sources. It is found that the signal received from a point source in the near-field is not bandlimited in the spatial frequency. Even though many solutions are available in the literature to combat this, they require the modification of the array's aperture. This may not be practical in the passive well-integrity evaluation problem. Through the investigation of the theoretical array's steering vector, a condition was derived that when satisfied guarantees an aliased-free localization. This condition has been validated with extensive numerical simulation as well as experimental analysis. Effectively, the condition extends the operating frequency range of the array without the need to modify the aperture.

In most situation, it is desirable to have less sensing device. This is because additional sensing devices will drive up cost as well as the complexity of the circuity. To optimize the trade-off, the third study focuses on localization a single sensing device. Here, it is found that recording from a single moving sensor of a known trajectory can be used to form the one sensor array (OSA) that achieve localization performance close to that of the Cramer-Rao Bound (CRB) of a stationary array. However, this conclusion is restricted only to harmonic sources. For non-harmonic sources, a new approach called the differential received signal strength OSA (dROSA) is proposed. As the dROSA approach does not require phase compensation, it is not restricted to harmonic sources as in the OSA.

Lastly, other than localizing, the classification of sources are also essential to a passive well-integrity evaluation system. To that end, a support vector machine learning approach is proposed to classify the type of leakages to four categories: (i) Liquid-to-Liquid (L2L), (ii) Liquid-to-Gas (L2G), (iii) Gas-to-Liquid (G2L), (iv) Gas-to-Gas (G2G). It is found that the approach provides $>$ 80% of correct prediction on 1800 of the acoustic recording collected over 10 different oil field.

AUTHOR's PUBLICATIONS

Journals

[1] A. R. Venna, **Y. Y. Ang**, N. Nguyen, Y. Lu, and D. Walters, "Support-Vector-Machine Phase Classification of Downhole Leak Flows Based on Acoustic Signals," *Petrophysics*, vol. 59, no. 06, pp. 841–848, 2018.

[2] **Y. Y. Ang**, N. Nguyen, and W. G. Seng, "Multiband Grid-Free Compressive Beamforming," *Mech. Syst. Signal Process.*, (submitted pending Major Review).

[3] **Y. Y. Ang**, N. Nguyen, and W. G. Seng, "Aliasing-Free Nearfield Localization using Linear Array," *Appl. Acoust.*, (submitted)

Conferences

[1] **Y. Y. Ang**, N. Nguyen, J. P. Lie, and W. S. Gan, "Localization of harmonic source using a single moving sensor of known trajectory," in 2017 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA ASC), 2017, pp. 324–328.

[2] **Y. Y. Ang**, N. Nguyen, J. P. Lie, and W. S. Gan, "Grid-free compressive beamforming using a single moving sensor of known trajectory," in 2017 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA ASC), 2017, pp. 329–332.