Oil Reservoir Monitoring using Ultra-Wideband Radar Technology

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***Abstract*— Oil-reservoir management using measurements and control techniques have been in use by oil and gas industries to improve the production and maintenance of the existing oil reservoirs. In the course of this project the applications of UWB radar systems and techniques to acquire near real-time information about the oil reservoir conditions are studied. Various oil reservoir structures such as oil wells, with both concrete or metal casings, and heavy-oil reservoirs (i.e., oil-sands) have been investigated. Different types of electromagnetic sensors and processing techniques are developed for these applications. The results of this research to enable the rapid industrialization of the proposed radar system for oil reservoir monitoring.**

I. Introduction

OIL reservoir monitoring using radar imaging techniques for maintenance and production enhancement has recently been introduced and developed as a new concept in the oil and gas industry. Consequently, oil reservoir monitoring has become an essential approach for oil and gas companies to obtain information about reservoir conditions for their management. Gaining a better understanding of the oil reservoir condition, through remote sensing, using ultra wideband (UWB) radar systems is the objective of this research. To achieve this goal, various oil reservoir structures have been considered for investigation. Different measurement and simulation scenarios are considered to demonstrate the UWB radar performance for these applications. Moreover, different antennas capable of radiating in oil reservoir condition are designed, fabricated and used in the experiments. A compendium of these results is summarized in this report.

II. Sensors for UWB radar imaging

The proposed UWB antennas are shown in Fig. 1. Both of these antennas are capable of radiating in oil reservoirs such as crude oil, within oil wells, and in oil-sands. The antenna shown in Fig.1 (a) is a Transverse electromagnetic antenna (TEM) designed for oil well medium [1]. This antenna is modified for better radiation characteristics in oil medium. Since the antenna is made of metal, it can be used for high power applications as well. Fig. 1(b) shows the miniaturized Vivaldi antenna that can radiate in both oil-sand and crude oil [2]. This antenna is miniaturized to make the installation easier in the reservoir.

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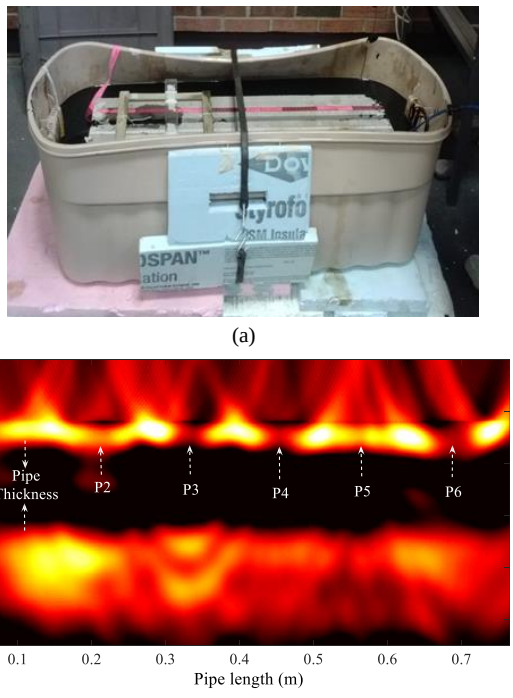
(a) (b)

Fig. 1. Designed sensors for oil reservoir monitoring, (a), TEM horn antenna,(b) miniaturized Vivaldi antenna, Photos are taken from [2], [3]

III. Case study results for different oil reservoir structures

The research is carried out on three different types of oil reservoirs. For all the three cases thorough study of pulse propagation, signal processing and imaging techniques are done. To observe the performance of the UWB radar system for these applications, different measurements are done on simplified lab prototypes.



(a)

(b)

Fig.2. (a) emulated section of a concert cased oil well, (b) radar image of the oil well section. Photos are taken from [3]

A. *Oil wells with concrete casing*

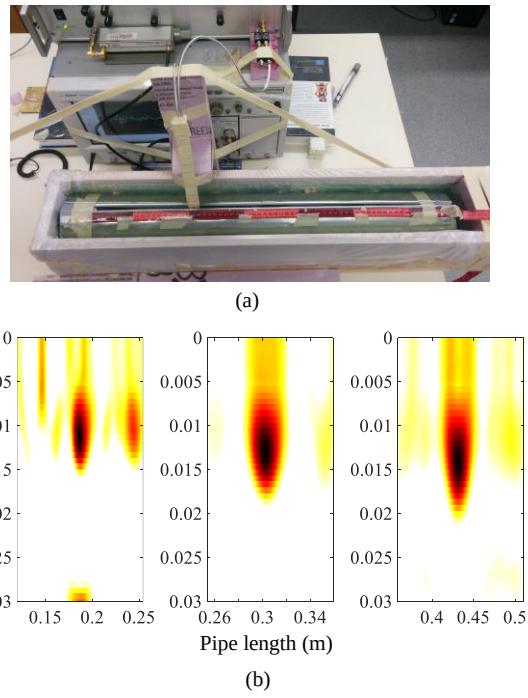
A considerable number of oil wells are cased with concrete. Therefore, the possibility of imaging perforations of the oil wells with UWB radar is studied. An emulated concrete cased oil well section, shown in Fig. 2(a), is used in these measurements. Measurement setup contains a UWB radar system, a perforated concert pipe, crude oil and a container, *c.f.* Fig. 2(a). Details of this study can be found in [3]. The reconstructed image of the oil well section is shown in Fig. 2(b), which shows the perforations' location and anomalies. The anomalies are perforation clogging conditions, which is due to bitumen or other organic materials.

B. *Oil wells with metal casing*

Oil wells are mostly cased with metal casing. Therefore, we also want to examine the adaptability of UWB radar for detection and imaging of perforations in a metal cased well. The experimental setup and reconstructed image of the perforations are shown in Fig.3. The ability of UWB radar for corrosion detection in metal casings is also demonstrated. Detection and imaging of an anomaly in a metal background, such as pipe, using radar is very complicated. Hence all the required knowledge such as calibration procedure and pulse characteristics are studied.

C. *Heavy oil reservoirs*

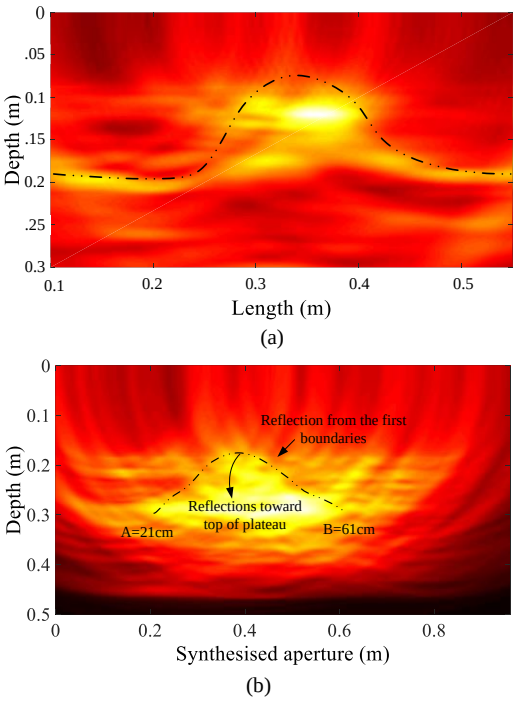
Heavy oil reservoirs are another huge source of oil which is in the form of oil-sand. The oil extraction procedure is different than of oil wells. Steam assisted gravity drainage (SAGD) is one of successful methods for heavy oil extraction. Monitoring the steam growth provides very valuable information to optimize the process and having more efficient production. Application of UWB radar for detection and imaging of steam growth pattern is studied in [2]. A simplified lab prototype is used to observe the radar performance. The reconstructed image of the wet area in the emulated steam chamber is shown in Fig. 4. As can be seen radar can detect and image the wet area and map the steam contours.



(a)

(b)

Fig.3. (a) emulated section of a metal cased oil well, (b) radar image of the oil well section



(a)

(b)

Fig.4. Steam chamber detection and imaging using radar, (a) using radar sensor at the top, (b) using radar sensor on the sides. Photos are taken from [2].

IV. Future Carrier Plans

I would like to continue my research in the field of radar imaging applied for different research areas.

As of today, we have developed the necessary concepts for radar imaging systems, both electromagnetic and signal processing fields, for oil reservoir monitoring. The next step will be the development of the radar system independent of lab equipment. Industrialization of the developed technology is the ultimate goal of this research. Here, I would like to thank MTT for MTT-S Graduate Fellowship program which enabled me to work on this project.

I would like to set my future carrier engaged in both academia and industry, since I believe strong industry needs academia and vice versa.

References

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[3] D. Oloumi, M. I. Pettersson, P. Mousavi, and K. Rambabu, "Imaging of oil-well perforations using UWB synthetic aperture radar," *IEEE Trans. Geosci. Remote Sens.*, vol. 53, no. 8, pp. 4510–4519, 2015.