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Drone-Borne Synthetic Aperture Radar for GPR Applications: Buried Pipe Inspection

John J. Pantoja(1), Felix. Vega(1), Luciano Prado(1), Qingjie Yang(1), Bader AlAli(1), Chaouki Kasmi(1)(2), Laila Moreira(3), Dieter Lübeck(3), and Christian Wimmer(3)
(1) Directed Energy Research Centre, Technology Innovation Institute, Abu Dhabi, United Arab Emirates, https://www.tii.ae/
(2) Faculty of Electrical Engineering, Helmut Schmidt University, 22043 Hamburg, Germany
(3) Radaz Indústria e Comércio de Produtos Eletrônicos S.A., São José dos Campos, Brazil, https://www.radaz.com.br/

Abstract

A multiband polarimetric synthetic aperture radar was used to study subsurface piping under desert conditions. In Abu Dhabi, United Arab Emirates, a measurement campaign was performed using a drone-borne synthetic aperture radar to obtain microwave images in three frequency ranges: P, L, and C-band. Typical reflections from this environment are identified. Results show that the system is suitable for subsurface inspection of buried piping, particularly in L band.

1. Introduction

Synthetic aperture radar (SAR) is a well-known technique for microwave imaging. These systems are borne on satellites, airplanes, and, in the recent years, on unmanned aerial vehicles (UAVs). Some advantages of using UAVs for SAR survey, include higher signal-to-noise ratio, the possibility of data acquisition in circular, helical or elliptical patterns, and the use of multiple frequency bands [1]. This paper presents the results of a drone-borne SAR survey conducted in a desert environment using three frequency bands: P, L, and C. The system's capability to detect buried objects, such as pipelines, is analyzed.

2. Experimental Setup

The survey was carried out using the Synthetic Aperture Radar RD350 Explorer from Radaz. The system operates in three different frequency bands: P, L, and C. It comprises a horizontal-polarization receiver in the P band, a vertical-polarization receiver in the C band, and vertical/ horizontal-polarization receivers in the L band. In addition, the receivers can process interferometric signals in P and C bands, and polarimetric signals in L band. Additional details are explained in [2].

The test was performed in a desert area of Abu Dhabi, United Arab Emirates (UAE), in proximity to farms and agricultural facilities. During the survey, a total area of 0.25 km^2 was scanned using five linear flight paths. The radar was mounted on a drone DJI Matrice 600, and the drone flew at 120 m in height. A set of 4 corner reflectors with squared sides were distributed in the survey area to have references on the ground. The recorded data were processed using a back-propagation algorithm for microwave imaging [3]. Survey, processing, and analysis of data were developed in the frame of a collaborative project between the Technology Innovation Institute and Radaz S. A.

Figure 1 shows the system used for the test and the inspected area. The survey area includes farms, roads, sandy terrain with some plants, and some infrastructures of water distribution system for the farms.

Figure 1. Drone-borne SAR system in the survey area.

3. Results

Figure 2 shows the processed results, which combine the three frequency bands in a colored SAR image. The image clearly shows the four corner reflectors that were used as a reference for the calibration of the radar and the scene. Superficial details, such as trees, shrubs, and fences, are mainly obtained with the C band, which corresponds to red color in Fig. 2. P band provides information on trees and metal objects on the surface, such as fences and metal structures. It also presents details of rubble on the surface and some information about buried pipes since the P band can penetrate many meters into dry sand.

The L-band image is the green component of Fig. 2, where it's possible to see the scattering from crops and metallic structures in the farm area. Fig 2 also shows two strong scattering green lines in the desert area, corresponding to

water-distribution system buried pipelines, buried at an average depth of 1m and detected by the L-band radar. The discontinuity in the pipeline images is probably due to a variation of the burial depth. Particularly, the pipeline on the right side of the image is not completely seen due to the terrain variation.

Additional details of the pipelines can be seen in the SAR image obtained for the L band in vertical polarization shown in Fig. 3, which clearly shows the pipeline on the left and some pipeline sections on the right. As the incident electric field is perpendicular to the pipe's axis for vertical polarization, the pipeline exhibits a resonance effect due to creeping waves [4] that intensify the scattered signals measured by the radar at this polarization and frequency band.

4. Conclusions

A polarimetric multiband SAR system was used to analyze a farm area under desert conditions. The use of a multiband system provides the capability to detect different kinds of objects and details of the area of interest without loss of resolution. Details of the crops, trees, and structures were clearly identified using the three frequency bands of the system. In addition, 1-m depth buried water pipelines were detected in the P and L-band images.

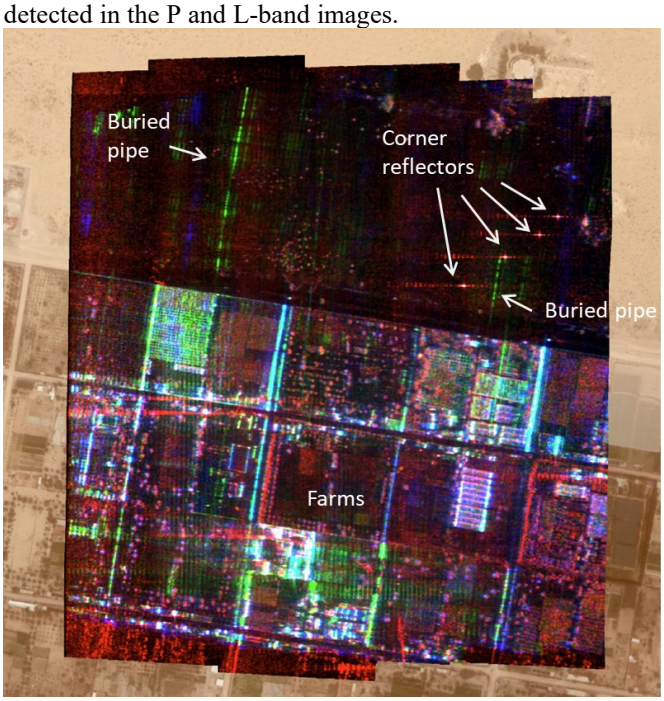

Figure 2. Colored SAR image obtained during the survey. Color codes are red for C band, blue for P band, and green for L band.

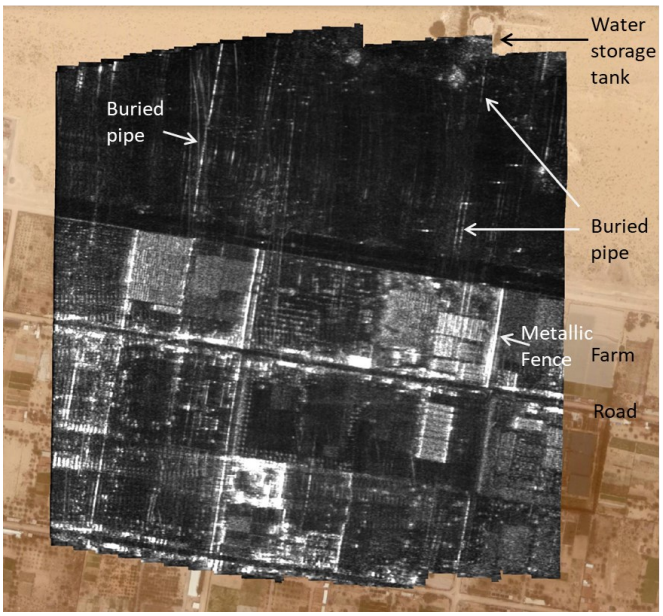

Figure 3. SAR image for L band in vertical polarization.

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