Electromagnetic Characterisation of Terrain for Unconventional Petroleum Exploration

Maurice Ezeoke[1], *Kenneth Tong*
Department of Electronic and Electrical Engineering
University College London
London, England
uceemse@ucl.ac.uk

Kenneth Mubea
Department of Geography
University of Bonn
Bonn, Germany
mubea@uni-bonn.de

***Abstract*— A method to characterize the electromagnetic (EM) signature of barefaced terrain using 3D computer electromagnetic models (CEM) for radar applications is presented. Five barefaced terrain types with different electrical, physical and chemical properties were investigated. They include both homogeneous and heterogeneous terrain types particularly beach sand, gravel and pebble acquired locally and oil sands from Nigeria. The approach develops CEMs using reflectance spectroscopy and dielectric permittivity data. First geochemical signatures were determined using reflectance spectroscopy in the Near Infrared region while dielectric properties were experimentally determined at L-, C- and X-band for multi-frequency radar. Both viscous and hard oil sand indicated resonance effects in the upper C-band. The results provide new information on the complex electrical permittivity $\varepsilon^*(\omega)$ and loss tangent, $\tan\delta$. Finally a laboratory based approach to measure the relationship between sensor configuration and terrain backscatter for 0.013m^3 of terrain samples using microwave measurement techniques in an anechoic chamber is outlined.**

I. INTRODUCTION

Interest in the discovery and exploration of unconventional petroleum reservoirs (UPR) such as oil sands and shale rock have been rekindled due to high oil prices, continual increase in global demand for energy and terminal decline of conventional petroleum fields. Estimations suggest that over 817 billion barrels of synthetic crude derivable from oil sands remain undiscovered in 22 countries including Kazakhstan, Russia and Nigeria. Petroleum exploration involves an interdisciplinary team traditionally led by geologists who use in-situ geo-physical methods like seismology and well or borehole logging to identify direct or indirect evidence of conventional oil reservoirs on land. UPRs such as oil sands are located on the surface to depths of 100m raising the possibility of microwave imaging for UPR exploration [1- 3].

Air or space-borne radar remote sensing provides the ability to gather information about an area, target or phenomenon over difficult to access areas in day and night times using electromagnetic (EM) waves. Target information is contained in the backscattering coefficient (σ^0). In the radar image this shows up in the variation of image tone. The backscattering coefficient (σ^0) or radar cross section (RCS) depends on geometric factors related to target surface attributes and electric factors due to dielectric properties of soil and vegetation for specific wavelengths. In addition to wavelength (or frequency), other sensor parameters such as incident geometry, polarization and resolution affect (σ^0). For farmland a relationship between σ^0 and roughness has been identified while other results show diverse scattering relationships between sensor and terrain parameters [4-7].

The development of accurate algorithms for the solution of backscattering problems is important whether terrain characterization is performed offline or *in situ* onboard the air or space platform. This is usually a challenging task owing to the non-linear and non-unique properties of the problem which cause the EM signature of terrain to overlap. This paper develops a method to characterize terrain for the exploration of UPRs using 3D computer electromagnetic modeling (CEM). CEM has varied applications to several fields of remote sensing including meteorology, medical imaging, military reconnaissance and mining.

The proposed method will have wide application to terrain classification for remote sensing and involves a three step process:

Step-1: Experimentally obtain the Geochemical Signature by using reflectance spectroscopy.

Step-2: Analyze the component distribution obtained in the first step as an initial guess before experimental measurements of dielectric permittivity.

Step-3: Input dielectric permittivity data from second step in to CEMs which are post-processed to provide the EM reflectivity, RCS or signature of the terrain. Use of permittivity data reduces the complexity of the CEM model to only surface roughness.

At each step of the process, results were compared with literature. In section 2 we briefly introduce the theory and measurement process while section 3 outlines some experimental and modeling results. In section 4 we discuss a

---

[1] *Petroleum Technology Development Fund and National Space Research Development Agency*

978-1-4799-2035-8/14/$31.00@2014 IEEE