SAR Signature of Oil Sands for Petroleum Exploration

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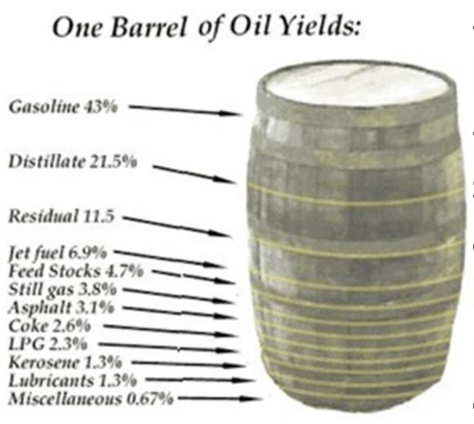
Synthetic Crude Oil



Derivatives from SCO

~ Roughly 1800 kg of oil sand is required to create one barrel (42 gallons) of synthetic crude oil (SCO).

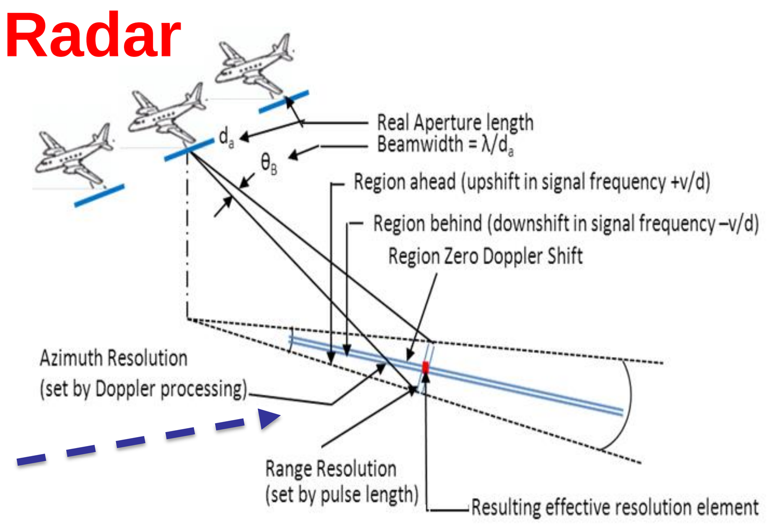
~ SCO like conventional crude oil drives almost every sphere of human activity including transport, commerce and industry.

Fact. Global demand for petroleum exceeds proven reserves. Only Canada and Venezuela currently explore and produce SCO by processing bitumen from oil sands.

Issue. Oil sands also exist in Russia, Nigeria, Kazakhstan and Saudi Arabia but difficult to explore.

Synthetic Aperture Radar

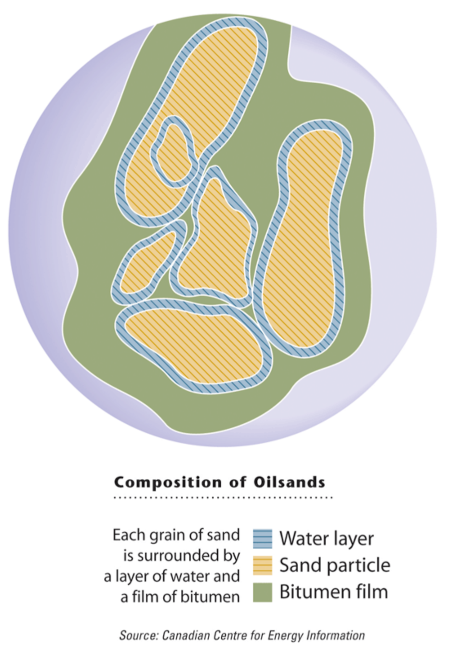
~ Synthetic Aperture Radar (SAR) is an electromagnetic (EM) imaging radar that uses the processing of a synthesized antenna to achieve high resolution from air or space-borne platforms.



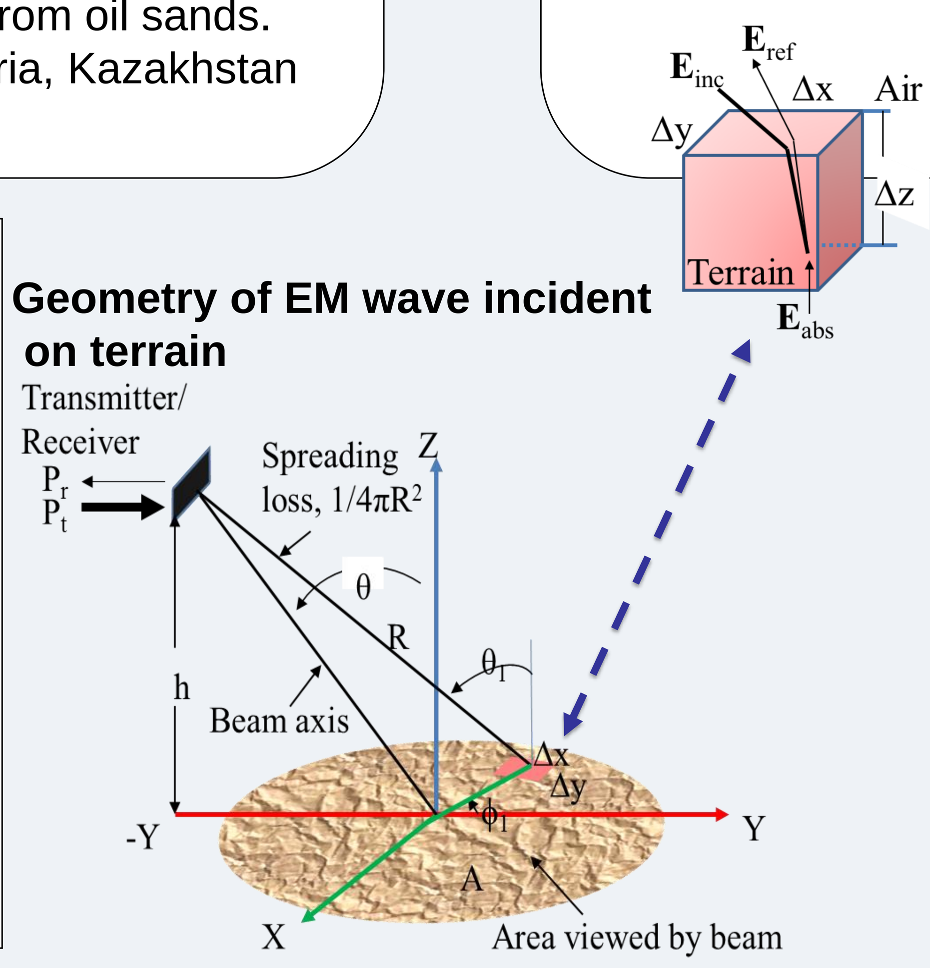
Resulting resolution element depends on range and azimuth.

Oil Sand

- Loose sandstone saturated with dense, sticky and viscous bitumen.
- Sand is the major grain, clay is the finer matrix while bitumen is the cement that joins grain and matrix to form oil sand.
- Weight percentage composition varies with depositional location.
- **Challenge** to identify physical and electrical properties to enable identification of oil sand from other terrain using SAR.



Geometry of EM wave incident on terrain



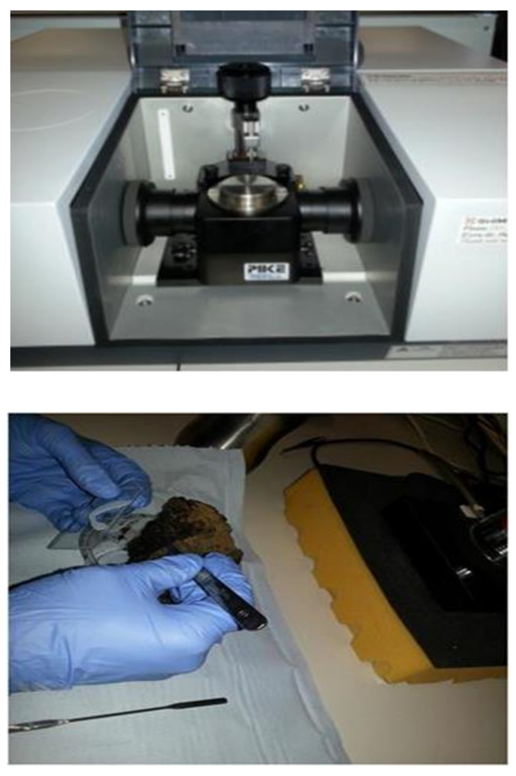
Radar Signature of Terrain

- Received power for adjacent pixels correspond to differences in magnitude of scattering coefficient σ^0_{rt}.
- For area extensive terrain target the SAR scattering model is given by:

$$P_r(\theta) = \left(\frac{P_{tx} G_{tx}(\theta) G_{rx}(\theta) \lambda^3 \Delta R_{rg}}{(4\pi)^3 k T_e R^3 L_s 2v} \csc\theta \right) \sigma^0_{rt}(\theta)$$

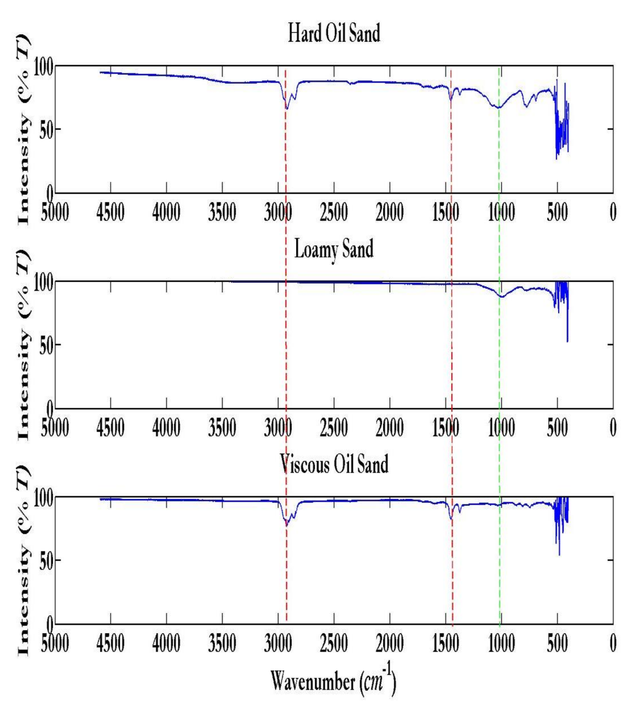
- Establishing the relationship between σ^0_{rt} and intrinsic electrical and physical properties of oil sand is key to using SAR for oil sand petroleum exploration.
- This involves development of terrain scattering models, measurements of physical and electrical properties for model calibration and use of real scattering measurements.

Experimental Measurements and Results



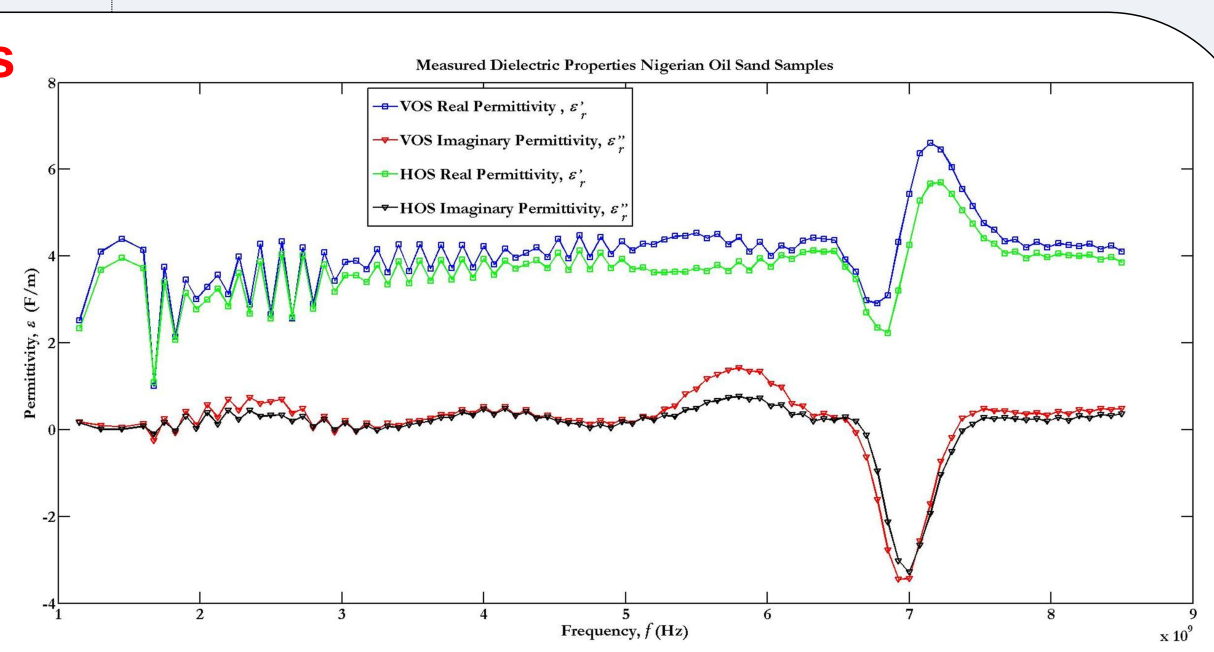
I. FTIR Spectrophotometer and Microslides

II. Hard (HOS) and Viscous Oil Sand (VOS)



III. FTIR Results indicating presence of Sand and Bitumen

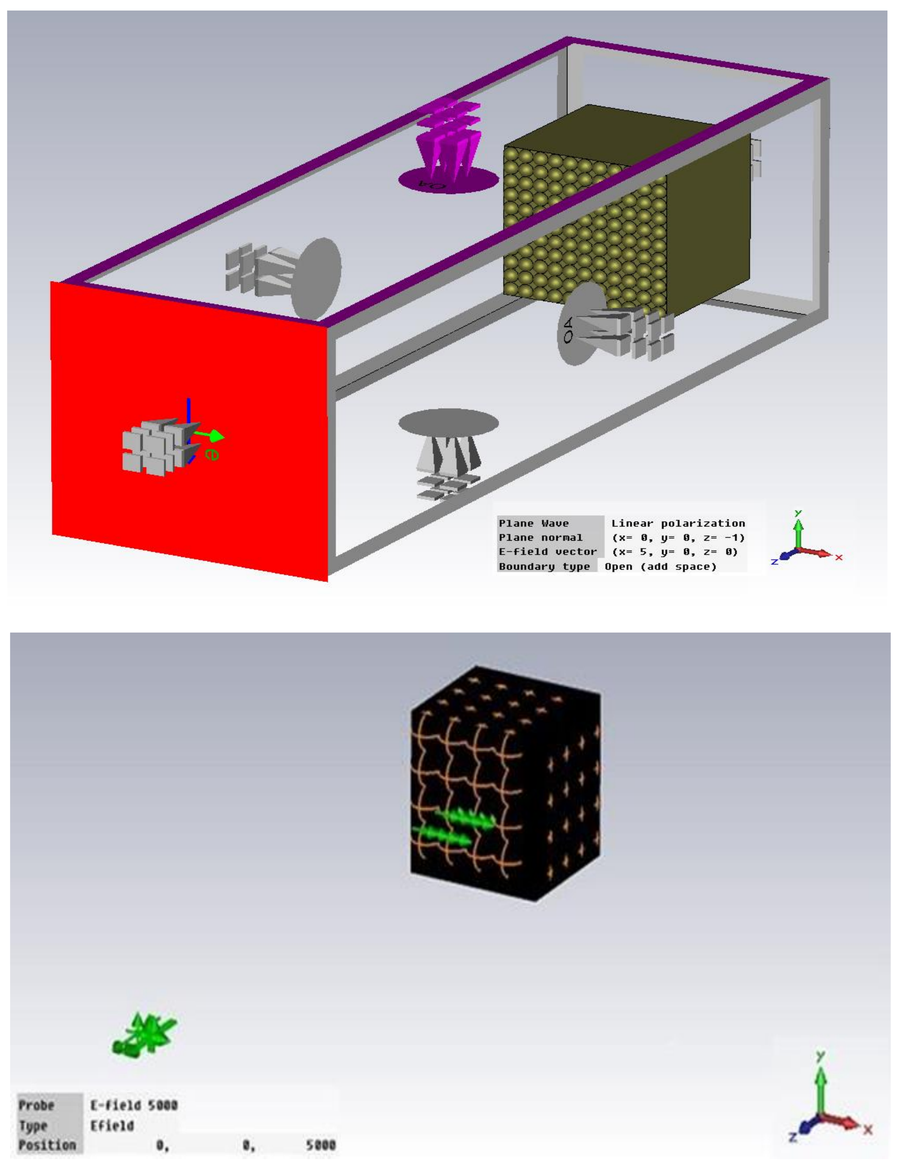
IV. Agilent ENA, Dielectric Probe Kit and Samples



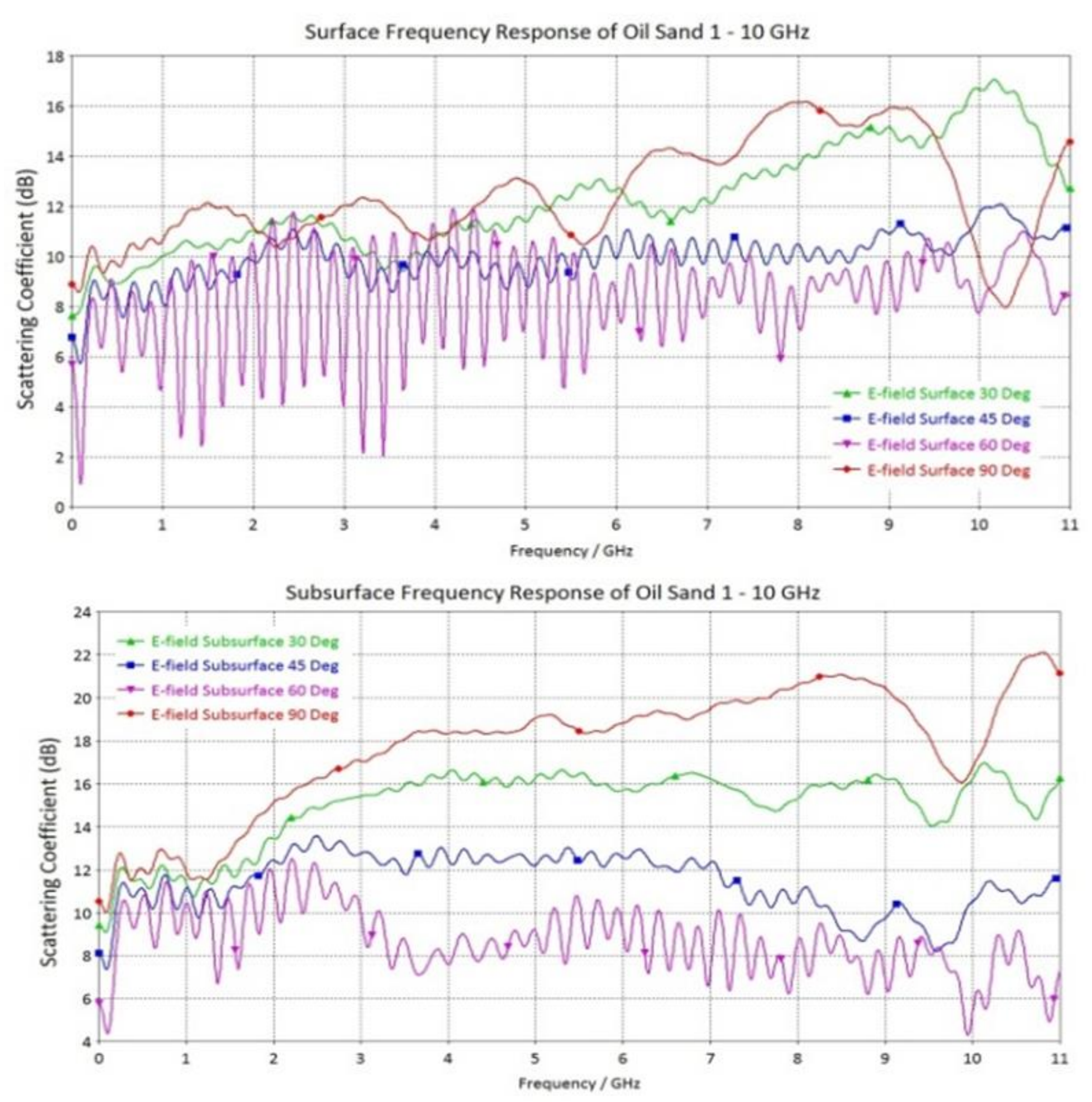
f (GHz)	VOS ε'_r	VOS ε''_r	HOS ε'_r	HOS ε''_r
1.15	2.515	0.179	2.335	0.159
5.05	4.124	0.158	3.701	0.139
8.5	4.106	0.494	3.853	0.365

V. Electric Properties of Oil Sand

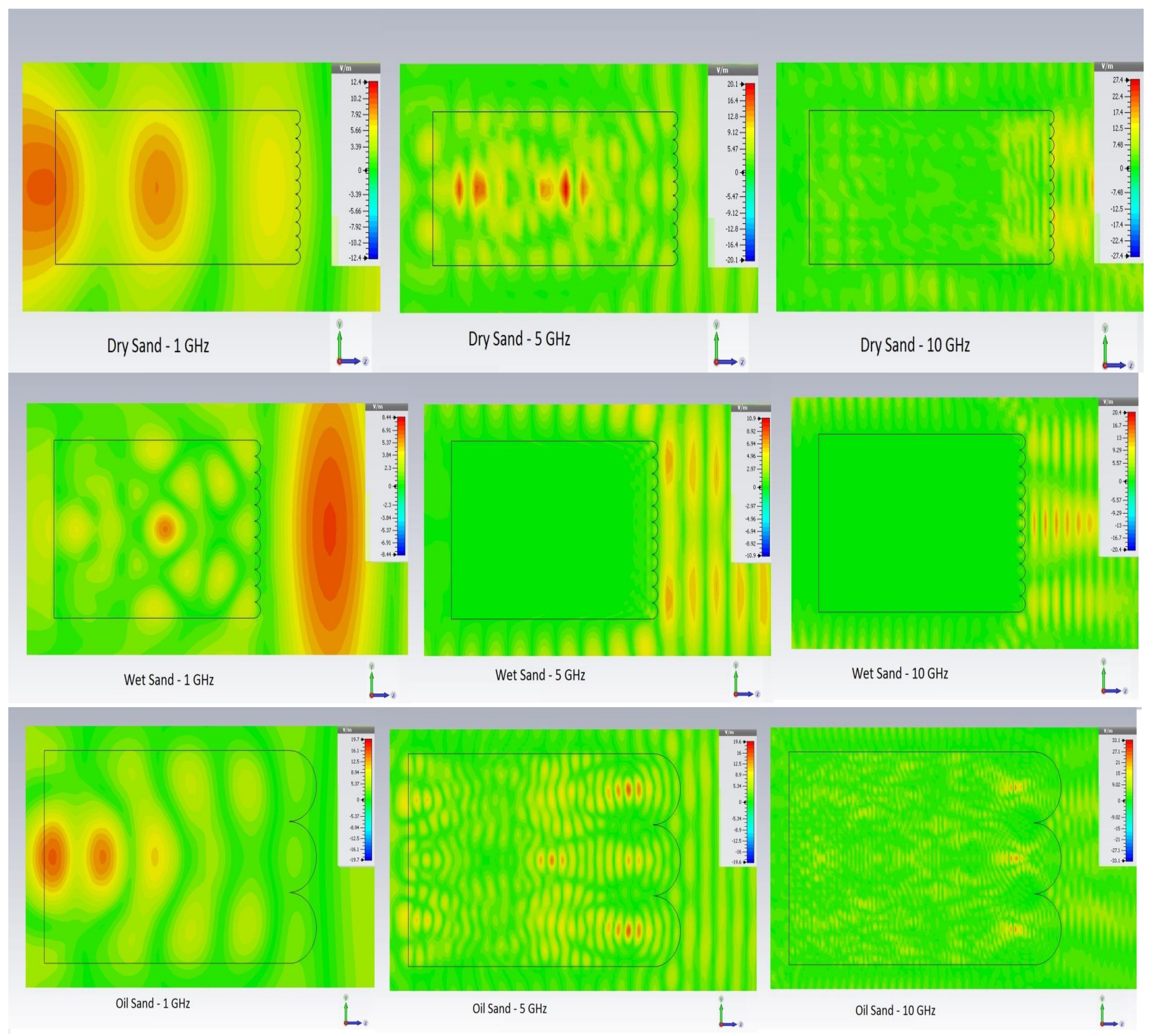
Modeling EM Backscatter Signature of Oil Sand



Generic model set up with measurement probes and created curves



Surface and subsurface backscattering response for different viewing geometry and frequency



2D/3D Phase plots showing overview of scattering from different terrain

Analysis

- FTIR analysis of HOS and VOS successfully determined the presence of a substantial amount of bitumen within both samples. This was observed by reduction in reflectance profile in the 2924 cm^{-1} and 1450 cm^{-1} bands while presence of sand was seen by comparison of absorption effects in the 1083 cm^{-1} band.
- Dielectric measurements for 1 – 8.5 GHz frequency indicate (1) strong similarities in measured permittivity values for both samples and (2) Kramers-Krönig relationship between real and imaginary permittivity values.
- Computer Simulation Technology MWS was used to generate 300 values of σ^0 for analysis. This corresponds to 300 combinations of sensor and terrain parameters with incident geometry, θ_i= 90°, 60°, 55°, 45°, 35°, 30°; frequency, f = 1 GHz, 5 GHz and 10 GHz and elemental volume 1m^3.
- Results from EM probes used in the models to measure scattering at δp = 0 cm, 0.1 cm and 0.5 cm show that at high frequency physical properties such as oil sand surface roughness dominate scattering while at low frequencies greater EM penetration occurs so that electrical properties of bitumen and moisture affect EM returns.

Conclusion

- Oil sand behaves as a low loss dielectric.
- Initial results have provided new information on the behaviour of oil sand terrain using FTIR spectroscopy, EM models and dielectric measurements.
- EM differences in physical and electrical properties between oil sand and surrounding terrain provide new opportunity for SAR remote sensing.

Continuing Work

- Perform scattering measurements, update already developed models and validate with historical SAR data

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