IFSAR Applications in Semi-Arid and Arid Environments

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SUMMARY

Radar remote sensing has come of age over the past several decades, with improvements in collection, processing, and cost-- benefitting government and commercial users alike. Well researched and proven applications include topographic mapping, security, surface geology analysis for oil and gas, and environmental monitoring. A lesser-known use though, is sub-surface imaging, where there is a high potential for additional applications in arid and semi-arid areas; hydrology, detection of subsurface structures, and archaeology.

This paper provides an examination of commercial airborne IFSAR systems, interferometric RADAR, and it's use in surveying, with particular attention to applicable techniques for arid environments, including precision land surface analysis and ground subsidence.

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Because of their long wavelengths when compared to the visible and infrared, microwaves have special properties that are important for remote sensing. Longer wavelength microwave radiation can penetrate through cloud cover, haze, dust, and all but very heavy rainfall**.** Radar**,** an active microwave sensor**,** provides its own illumination, and therefore is operable day or night. . Radar sensors also have the ability to characterize surface types and different materials.

Interferometric synthetic-aperture radar (IFSAR), such as that employed on Fugro's GeoSAR platform, is a powerful technique for mapping topography at a high spatial resolution over large areas. Over time, improvements in the ability to generate accurate IFSAR products at regional or global scales quickly and at a reasonable cost has seen the rapid infusion of this technology into a variety of applications. This ability to rapidly collect accurate, high-resolution geospatial information offers unprecedented benefits to countries wishing to build a National Spatial Data Infrastructure (NSDI).

As airborne IFSAR systems have evolved and shown improvements in resolution and height acuity, additional applications have been discovered. The accuracy of the data lends itself to generating precision land surface analysis and structural detail in both semi-arid, and humid or tropical environments. Tectonic movement, or ground subsidence, from several sources have been successfully detected using interferometric radar techniques.[1]

IFSAR system height and image data can simultaneously provide topographic information at two scales. Using the topographic data directly, topography at the DEM posting provides information about geologic structures such as faults, volcanic structures, and landform size and extent. The associated SAR imagery, which is sensitive to the surface roughness on the scale of the radar wavelength, provides information about the micro-topography of the surface. The combination of the two scales can be used to infer information about the surface geology.

A major benefit of radar imaging is that these long wavelength (low-frequency) signals have the ability to penetrate the ground, allowing for investigation and mapping of subsurface features. This is an important, but to date, under-researched application area.

The presence (or absence) of moisture affects the electrical properties of an object. Changes in the electrical properties influence the absorption, transmission, and
reflection of microwave energy. Thus, the moisture content will influence how targets and surfaces reflect energy from a radar sensor and how they will appear on an image. Generally, reflectivity (and image brightness) increases with increased moisture content. For example, surfaces such as soil and vegetation cover will appear brighter when they are wet than when they are dry. Very dry soil appears smooth in a radar image, and for a given surface, longer wavelengths are able to penetrate further than shorter wavelengths.

Studies over the last several years have shown that low-frequency radar are capable of penetrating dry to moist soil, and that very low-frequency, such as P-band radar (below 435 MHz) is capable of penetration of depths down to 15m or more.[2] There are several factors that affect the ability to achieve these depths including; soil composition, incidence angle of the radar beam, and as already stated, soil moisture.

In the 1980's, the Bir Safsaf region in southwestern Egypt was an early, and important research site for radar detection of geologic structures covered by layers of sand. It was in this hyperarid area where spaceborne Shuttle Radar SIR-A and SIR-B mission radar were able to detect previously undiscovered fossil river systems. Subsequent studies in the area using the multifrequency polarimetric SIR-C/X-SAR system revealed important differences in information collected at different frequencies and polarizations. Results were combined with data from Ground Penetrating Radar (GPR), which are sensors mounted on portable equipment and typically in direct contact with the ground. Results based on the combination of using the two radar types (GPR and airborne SAR) proved to be successful in deriving the geological substructures and soil content—which are relevant for interpretation of the SAR images. This approach helped to better understand the backscatter radar signal at different frequencies. Analysis of L-Band SAR images and GPR profiles for Bir Safsaf revealed deeper structures (down to 3 m), which lead to the conclusion that the use of lower frequency SAR (P-Band below 435 MHz) would be able to detect even deeper structures (down to 5 m or more).[3] This conclusion is validated by data acquired by the GeoSAR system

A 2001 study using the French National Aerospace Research Center's (ONERA) RAMSES system used a similar approach. Subsurface structures in the Pyla Dune area in the Bordeaux region of France were imaged and studied. RAMSES was an experimental testbed platform used to advance various radar (SAR) technologies. SAR L-Band data from RAMSES and AIRSAR was combined with GPR data for mapping lithology, moisture content and sedimentary structures. Results showed deeper penetration of lower frequency L-Band than C-Band. P-Band frequency (~ 400 MHz) use revealed great potential for detecting moisture, buried structures down to 10m in wet sand, and at depths up to 18m in dry sand.

Another study showing the benefits of radar data for subsurface imaging was conducted in the Great Sandy Desert of Western Australia, where sandplains, dunefields and shrub-steppe vegetation obscure much of the subtle topography and underlying fossilized sedimentary rocks. NASA-JPL's AIRSAR data have demonstrated the benefits of polarimetric radar for revealing more information about the composition of the terrain than using comparable optical satellite imagery.[4]

Fugro EarthData's GeoSAR P-band sensor has confirmed the basis for the ground penetration claims found in these studies. GeoSAR data over the Mojave desert, near Edwards Air Force Base has revealed a mostly submerged geological formation. Though these findings are encouraging, more conclusive work remains.

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