Geophysical Research Abstracts,
Vol. 11, EGU2009-5343-2, 2009
EGU General Assembly 2009
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Combined Holographic Subsurface Radar and Infrared Thermography for Diagnosis of the Conditions of Historical Structures and Artworks

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RASCAN radars are a completely unique and innovative type of subsurface radar. These systems operate with continuous wave, un-modulated, discrete frequencies around 2, 4 or 7 GHz depending upon the model. Images are recorded by sweeping the small size (6 cm) cylindrical horn antenna array across an investigated surface, with the transmitter producing five discrete frequencies which are recorded at two receivers with parallel and cross polarization relative to the transmitter. The reflected signals are mixed with an internal reference signal to create a holographic image of the subsurface, with resolution of 1/2 wavelength or better. The use of five frequencies and two polarizations ensures detection of targets with arbitrary orientation at depths up to about 2 wavelengthsrm

RASCAN radars have previously shown great promise for shallow, very high resolution scanning of stone, wood, mortar, plaster, and other dielectric materials that are important in art and architectural preservation. A particular sensitivity to moisture - even at very low concentrations - has been demonstrated, and the knowledge of moisture presence is of critical importance in many antiquities.

In addition, RASCAN produces plan-view subsurface images in real-time, with no post-processing. Subsurface targets are shown with their true plan-view shapes (as opposed to the hyperbolic reflection patterns typical of impulse radars images of targets of any shape. These characteristics make RASCAN a tool readily applied and interpreted by users with no special geophysical training.

However, as with all geophysics, there is inherent non-uniqueness. The actual source or composition of subsurface targets seen in the images cannot be known from RASCAN alone. In some cases, the targets can be identified through historical research of intrusive testing. But, particularly for undocumented high-value antiquities, target identification purely by non-destructive means is desired.

We have tested the side-by-side use of RASCAN radar and infrared thermography (IRT) as a means of alleviating the non-uniqueness problem. Coincident RASCAN and IRT images have been recorded for laboratory mock-ups of stone, wood and plaster structures and artworks containing subsurface cracks, voids, moisture, insect damage, supports, repairs, and the like. In addition, some initial side-by-side testing has been performed on actual historic structures and artworks.

Since both RASCAN and IRT produce real-time, plan-view images, they are easily overlain and compared, and both can be interpreted visually – especially by persons familiar with the particular item under investigation. Because they are sensitive to completely independent physical properties (dielectric constant for RASCAN and thermal conductivity and heat capacity for IRT), this comparison can allow confident identification of target materials and conditions. Our testing confirms that both are exquisitely sensitive to hidden moisture. Finally, instrumentation for both RASCAN and IRT is commercially available, relatively low cost, and easy to use and interpret – making this combination of methods a potentially powerful tool for workers engaged in the preservation and restoration of artworks and architecture.