Terahertz Scattering from Contaminants Embedded in Textile Rope and Sling Materials

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Terahertz Time Domain Imaging (THz-TDI) is a new technology that is rapidly being explored by researchers around the world with particular interest in non-destructive evaluation (NDE) applications for manufacturing, security screening, and medical imaging. This work expands the scope of THz NDE by investigating its potential as a new and innovative method for NDE of nylon ropes and slings, which are used throughout all branches of the military as well as the civilian construction, transportation and shipping industries. Ropes and slings are exposed to harsh environmental conditions as they are dragged through sand and dirt or exposed to seawater, and their strength is compromised when grains of sand or sea salt become deeply embedded between the rope strands and wear away at its nylon threads.

Until now, inspections of textile ropes and slings has been limited to subjective observations of the surface because the textile material is opaque to visible light. However, non-polar dielectric materials such as nylon and other plastics are mostly transparent to waves in the THz band (0.1 - 3.0 THz). In contrast, materials composed of polar molecules often possess characteristic resonances that trace out unique spectroscopic signatures in the material's refractive index. These spectroscopic features can be used for material identification and chemical mapping.

The application of THz-TDI technology to NDE of textile ropes and slings will require detailed understanding of complex scattering physics in random media. For textile slings, the background medium is a relatively wide, thin rectangular slab composed of interwoven strands of polymer fibers, with the potential for diffuse scattering of the THz beam from the random rough surface. Contaminant grains of sand/salt embedded in the textile sling may be approximated as small spheres on the order of 10s of microns in diameter, randomly distributed within the background. Thus, the grains act as Raleigh or Mie scatterers at THz wavelengths, with the relative degree of volume scattering dependent on the particle distribution and fractional volume of the grains.

This paper investigates THz scattering phenomena in textile sling materials by comparing THz laboratory measurements with electromagnetic scattering simulations based on analytic models. Tomographic THz images of sand and salt embedded in nylon sling material are also presented and a design concept for a prototype THz rope scanner is discussed. Military and civilian organizations alike would benefit from this innovative approach, as it will protect personnel and cargo from previously unseen hazards.