Non-Destructive Dielectric Constant Measurement of a Loss-less Dielectric Slab using Coherent Multipath Interference of a Wideband Radiation

Seyedmohammad Mousavi*[1], Roger De Roo[2], Kamal Sarabandi[1], and Anthony England[3]

[1] Electrical Engineering and Computer Science Department, University of Michigan, Ann Arbor, MI

[2] Climate and Space Sciences and Engineering Department, University of Michigan, Ann Arbor, MI

[3] College of Engineering and Computer Science, University of Michigan, Dearborn, MI

The knowledge of interaction of electromagnetic waves with natural and man-made materials is of great importance in today's engineering and manufacturing applications. The behavior of electromagnetic waves in homogeneous media is mainly dependent on medium's macroscopic parameter, the relative dielectric constant. The relative dielectric constant or relative permittivity of a material is an electrical property of the material, which changes the magnitude, phase, and direction of an applied electric field. The dielectric constant is mostly a complex quantity. The real part is related to the dipole moment per unit volume of the material, while the imaginary part is related to the dissipated heat. For a loss-less material, where there is no absorption or heat dissipation, the dielectric constant would be a real quantity. There are many techniques and procedures reported in the literature for the measurement of the dielectric constant of materials, such as quasi static method, cavity resonator method, transmission line method, and etc. However, these methods require direct sampling of a material, which is mostly destructive and sometimes impossible to perform for some targets, such as snowpacks on high altitude mountains.

This paper introduces a new and non-destructive measurement technique of the dielectric constant of a loss-less dielectric slab, such as a dry snowpack or freshwater lake icepack, using the Wideband Autocorrelation Radiometry (WiBAR). WiBAR is a recently developed microwave radiometric technique to measure the lake icepack or snowpack thickness. This technique offers a direct method to remotely measure the microwave propagation time difference of multi-path microwave emission from loss-less layered surfaces such as dry snowpack and freshwater lake icepack. The microwave propagation time difference through the pack, τ_{delay}, yields a measure of its vertical extent. The τ_{delay} is dependent on the dielectric constant of the pack, thickness of the pack, and the incidence angle. The elevation angular dependence of the τ_{delay} has been shown previously. Using the τ_{delay} measured by WiBAR at two different incidence angles, the dielectric constant and the thickness of the loss-less pack can be directly and non-destructively measured. We will leave issues that confound the retrieval, such as radio frequency interference and target imperfections of absorption, and volume and surface scattering for future consideration. An X-band instrument fabricated from commercial-off-the shelf (COTS) components are used to characterize the freshwater lake icepack at the University of Michigan Biological Station. The measurement were performed in H-pol configuration for a freshwater lake icepack of about 36 cm from nadir to 59°.