The Engineering Modelling of Electromagnetic Wave Scattering from Sea Ice by Surface-based Radar

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Over the past 20 years, the Northwest Passage has seen increased traffic with a record high 33 full transits in 2017, which included 3 full transits by a cruise ship carrying 1500 passengers. In addition, there are hundreds of oil and gas exploration and supply ship transits of the arctic annually. The majority of the Northwest Passage is in perpetual daylight from April to September, but fog, snow and poor visibility are common during this period. Although the ice pack melts or receeds in the passages during the summer months, ice floes move in and out of the channels pushed by wind and current, making open channels quickly ice-filled. Even ice strengthened vessels, such as icebreakers, are at risk of hull damage due to collisions with multi-year and glacial ice within ice floes. Finally, breaking even first-year ice is slow and costly in terms of fuel: it is more efficient to transit in open water, even if it adds tens or hundreds of miles. These factors necessitate the use of marine radars to not only navigate the channels, but also to detect and avoid ice.

Ice detection and avoidance is currently conducted using existing X-band or S-band marine navigation radars with additional ice processing software or hardware. These systems provide higher definition images to help the operator identify ice features, but do not allow the classification and identification of the type of ice: first-year ice which poses a minimal risk of damage to the vessel, and multi-year ice or glacial ice which poses a high risk of damage to the vessel. Research into improving the post-detection processing of surface-based radar has been conducted (eg. S. Haykin, B.W. Currie, E.O. Lewis and K.A. Nickerson, Proc. IEEE, 73, 233-251, 1985; J.R. Orlando, R. Mann and S. Haykin, IEEE J. Oceanic Engineering, 15, 228-237, 1990) but seems to have been neglected academically since then. Most manufacturers offer an ice navigation feature, but these systems are limited by the fact that they are based on existing marine navigation radars, as opposed to a purpose built ice detection and classification radar. Furthermore, whereas there has been significant research published on the classification and identification of ice from space-based and airborne radar, very little research has been published based on marine radar for this purpose.

From the research on space-based remote sensing and ice chemistry, it is well known that first-year, multi-year and glacial ice have different physical structures and dielectric properties (eg. M.R. Vant, R.O. Ramseier and V. Makios, J. Applied Physics, 49, 1264-1280 1978). First-year ice contains significant air and saline inclusions which inhibit penetration of the radar signal. Multi-year ice and glacial ice have little to no saline inclusions and allow the radar wave to penetrate and depolarize. This study develops simplified but reliable engineering models, based on computational electromagnetics, to predict reflected wave scattering from the various types of ice targets. These models are then used to explore the relationship between frequency, polarization and incident angle on the strength and properties of the returned wave, in order to improve the classification accuracy of first-year, multi-year and glacial ice types.