SMITH COLLEGE

Memo

From: Jay Frothingham
To: EGR 390 class participants
Date: October 28th, 2022
Subject: A Memo on Passive Radar Techniques Using Astronomical Radio Sources

Introduction

Students in the course EGR 390, a seminar on remote sensing, have been exposed to the basic technical principles of commonly used remote sensing systems. Through lectures and presentations, students have been able to discuss advanced applications of RAdio Detection And Ranging (radar), LIght Detection And Ranging (lidar), SOund Detection And Ranging (sonar), and Ground Penetrating Radar (GPR). With this background, students are equipped to understand and discuss published journal articles relating to different remote sensing systems and their applications. The purpose of this memo is to summarize one such article, giving engineering students a more detailed understanding of advanced applications of remote sensing.

Paper description

Peters, Sean T., et al. "Passive Synthetic Aperture Radar Imaging Using Radio-Astronomical Sources." *IEEE Transactions on Geoscience and Remote Sensing*, vol. 59, no. 11, Nov. 2021, pp. 9144-9159. doi: 10.1109/TGRS.2021.3050429.

Radio-based remote sensing techniques are commonly used to measure ice thickness and hidden conditions of glaciers. Glacial monitoring by necessity must be carried out on large geographical scales. The cost and hassle of using active radar systems to carry out glacial surveys on meaningful scales limit researchers to collecting survey data on a seasonal to yearly basis. However, glaciers can evolve on timescales as short as days or weeks, so yearly surveys are not capturing a complete picture of glacial behavior. The authors of this paper present work improving passive radar systems, systems that do not generate their own radio signals. Passive radar systems require far fewer resources than active radar systems, and could be a viable option for frequent large-scale glacial surveying.

In particular, the authors focused on the Sun as a source of opportunity signals for passive radar. Like many astronomical bodies, the Sun emits in the radio regime. A passive radar system for glacial monitoring can measure the strength of radio signals from the Sun and correlate the peaks of those observations to the peaks of reflected radio signals received from a glacier. The delay time between the source's peak and the reflected echo's peak corresponds to the thickness of the ice.

The researchers derived the radar equation in the case of passive radar and calculated the signal-to-noise ratio (SNR) of a passive radar system. They calculated how the delay time between an incoming signal and a reflected signal can be modeled when the source of a signal is moving relative to the receiver and the reflecting surface. From their calculations, the researchers were able to choose parameters appropriately for a field test.

In the field test, "the passive receiver remains stationary on the side of a cliff in Death Valley and tracks the Sun's moving reflection point…off the desert floor." The field test allowed the researchers to better characterize their designed system. While the desired application of this passive radar system is to measure ice thickness, the field test was more focused on collecting data and evaluating data processing techniques to determine how well the system can detect echoes rather than on translating those echoes into proxy depth measurements.

In processing the received signals, the authors took a four-part approach. First, data were segmented, improving the time required for processing at the cost of a reduced SNR. Next, radio frequency interference (RFI) was removed from the signals and the peaks of direct signals were correlated with their echoes. After correlation, amplitude, phase, and delay time of the echo peaks were extracted. From this extracted information, the authors were able to make Range-Doppler images indicating delay time and frequency. These images were generated using different integration times to demonstrate the effects of different processing parameters.

The authors found that their passive radar system successfully measured radio echoes from the Sun reflecting off a rough surface. They were able to recover information on range, phase, and reflectivity from the echoes. The statistical simulations the researchers carried out can inform future development of the system. The researchers performed a rigorous proof-of-concept with this paper. While they did not fully develop a system that can be used for their stated long-term goals of glacial monitoring, they did accomplish their smaller goals of characterizing and optimizing their passive radar system.

Thoughts

I chose this article because I am interested in radio astronomy, so I was excited to read about remote sensing applications that utilize radio astronomical sources. The authors focused on fairly specific applications of this research. They emphasized the potential use of these remote sensing techniques in glacier tracking. However, I think the topic is more broadly meaningful than that. Passive radar imaging using the Sun as a source is a powerful technique that may be attractive for use in other fields because of its resource-efficient nature.

Overall, I think this was a "good" paper. It was well-organized, and I appreciated that the authors justified the techniques they used. While there was a great deal of technical detail, the authors thoroughly explained the background concepts and motivations for their work.

If I could go back in time and pick a different paper, I would still pick this paper. It was an interesting look at the development process for new instrumentation. These authors have published papers on this subject in the past, so while still in the early stages, the work highlighted here is more sophisticated than just "does this work?" I really appreciated seeing how the authors applied statistics and simulations to evaluate their results and setup. It built nicely off of concepts covered in my Signals and Systems engineering course and my Astronomical Data Science astronomy course.

Conclusions

The purpose of this memo is to explain an advanced application of a remote sensing system. In this memo, I have summarized a paper presenting work on developing a passive radar system using astronomical radio signal echoes to monitor glacial conditions on long time scales and large geographical scales. This work is valuable for its innovative improvements on ground penetrating radar. This memo enriches students' understanding of the development and potential of remote sensing systems.