SMITH COLLEGE

Memo

From: Jay Frothingham
To: EGR 390 class participants
Date: October 6th, 2022
Subject: A Memo on Meteor Detection Using FM Radio Broadcasts

Introduction

Students in the course EGR 390, a seminar on remote sensing, have been exposed to the basic technical principles of Light Detection And Ranging (LiDAR), Radio Detection And Ranging (RADAR), and Sound Detection and Ranging (SONAR). With this background, students are equipped to understand and discuss published journal articles related to these and similar types of remote sensing systems. The purpose of this memo is to summarize one such article, giving engineering students a more detailed understanding of advanced topics and applications of remote sensing systems.

Paper description

Sethi, Himanshu Sekhar, and Nirvikar Dashora. "Novel Meteor Observations Using FM Radio Broadcast Over Gadanki, India." *IEEE Transactions On Geoscience And Remote Sensing*, vol. 60, 2022. ieeexplore.ieee.org/abstract/document/9810301.

RADAR systems to detect meteors already exist, but many of them are large, expensive, and very specialized in purpose. Similarly to how radio transmissions bounce off the ionosphere, radio pulses can bounce off pockets of ionized gases created in the wake of disintegrating meteors in the atmosphere. This paper proposes and tests a new meteor detection system which utilizes existing radio broadcast infrastructure to decrease costs and increase the accessibility of meteor research to amateur radio enthusiasts. Rather than bouncing a self-generated radio pulse back into a receiver, their system receives existing radio broadcast signals and detects what are known as meteor echoes present in the received signals.

The researchers used a common type of radio antenna, developed an algorithm to measure the strength and polarity of signals received with their antenna, and tuned into several radio stations located 40km away from the antenna. From their data, they identified signal characteristics consistent with different types of meteor echoes indicating different processes by which meteors disintegrate. There exist empirical formulas to calculate some physical properties of the detected meteors and the atmosphere. The researchers were able to do some calculations and compare their results to previously published results from other RADAR systems.

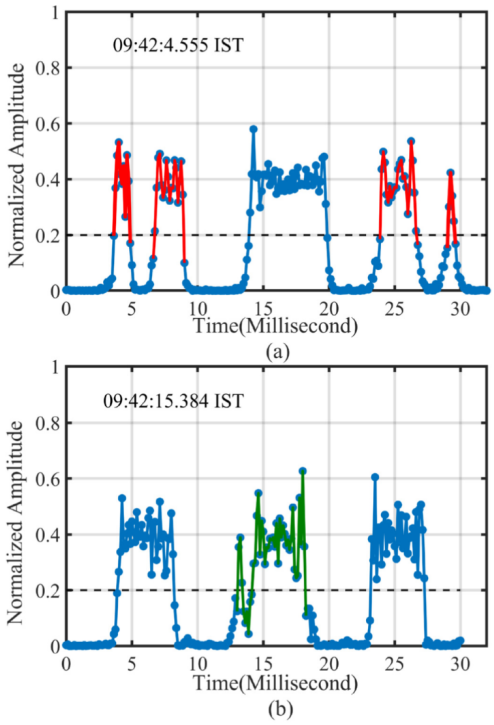

Fig. 1. Normalized amplitude of the continuous signal at 103.2-MHz FM broadcast received on August 14, 2020: (a) signal for the duration of 32 ms starting at 9:42:4.555 IST and (b) signal for the duration of 30 ms starting at 9:42:15.384 IST.

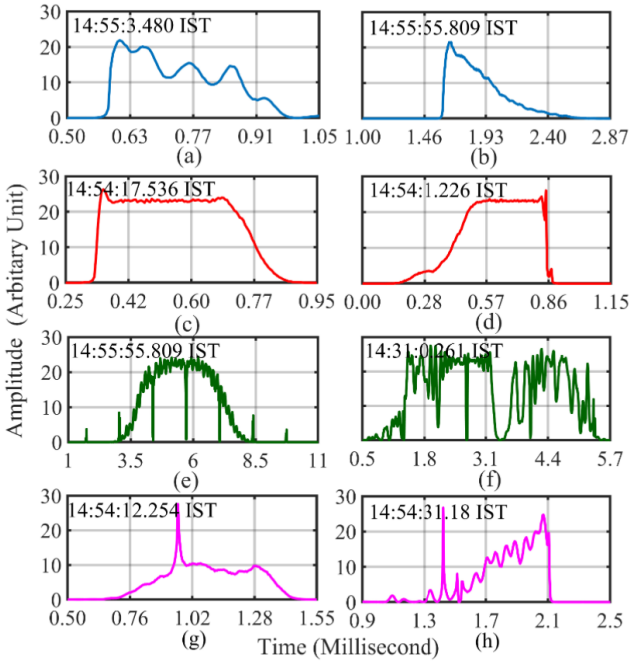

Fig. 2. Different types of the observed meteor echo on August 4, 2020: (a) underdense echo with Fresnel oscillations; (b) underdense echo with washed-out oscillations; (c) overdense echo with simple ablation; (d) overdense echo with differential ablation; (e) overdense echo with a beat pattern; (f) overdense echo with severe fragmentation; (g) ambiguous meteor echo; and (h) meteor event with both the fragmentation and the differential ablation.

Figures 1 and 2, above, depict detected signals that correspond to different types of meteor echoes. As proof of concept, this project succeeded in showing that a cheap, non-specialized system similar to those already in use by the amateur radio community can be used to detect meteor echoes. The authors still have a ways to go in terms of improving the algorithm they used to identify meteor echoes in their dataset, and being able to use their results to calculate reasonable quantities.

The researchers noted that due to the low power transmission of radio broadcast signals, the signal-to-noise ratio in their data was low. As a result, many of their quantities had large associated uncertainties. Additionally, they were able to detect a different population of meteor echoes when they changed the rate at which they sampled data. To me, this highlights that their project was not designed to answer any well-defined scientific questions. Instead, the researchers succeeded in simply showing that this system can work.

Thoughts

I chose this article because I am interested in astronomy, particularly in the radio regime. I was curious about the use of radio broadcasts to collect data about meteors. This research is fairly narrow in scope; the technical parameters and algorithm used in this project are only applicable to certain types of meteor echo detections in certain conditions. Meteor echo detection is already a somewhat narrow field, but I think the idea of using cheap equipment already in use by radio hobbyists as a way to increase participation and data collection could become more broadly

meaningful as more research is done. Perhaps future successes could inspire similar work in other fields.

That being said, I don't think it was a "good" paper. I found it difficult to determine what was significant and understand the context of the results. The authors did not explain the background concepts and the underlying physics of their methodology in much detail, and had too many distinct results presented, as their system was successful in some ways but not in others. If they had identified a few clear benchmarks by which to measure the success of their concept, the paper would have been much stronger.

If I had the opportunity to go back in time and pick a different paper, I still would choose this one. For all that the paper was difficult to understand, it did describe some very interesting work. I learned a lot about meteors, and how the definition/function of a RADAR system can be stretched to include inventive ideas. The content also connected well with some of the aspects of a previous Signals and Systems class that I really enjoyed.

Conclusions

The purpose of this memo is to explain an advanced application relating to LiDAR, RADAR, or SONAR. In this memo, I have summarized a paper presenting work on how existing radio equipment and broadcasts can be used to detect meteors as they disintegrate in the atmosphere. This work is valuable for showing a creative use of RADAR principles. This memo enriches students' understanding of RADAR's scope and applications.

Additional Reference

"Radio Meteor Listening." spaceweather, Marshall Space Flight Center, spaceweather.com/glossary/nasameteorradar.html. Accessed 6 Oct. 2022.