4-21-2023

High Frequency Radio Communication

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High frequency radio communication has been the most reliable form of communication for many decades. Over that period, we have learned and experienced times of enhanced signals along with complete radio blackouts. The purpose of this research is to collect and analyze radio signal data to see the evidence of various reasons as to why these phenomena occur. A radio antenna was set up at USU campus to retrieve the signals from beacon networks across the globe that transmit signals every 15 minutes. By tracking a few of these signals we can locate the times of discrepancies in the signals and see what could have caused them. In this study we were able to find periods of radio blackouts that were linked to solar activities that occurred on those days. The events that we were able to correlate to the signal discrepancies were a solar energetic proton event as well as a powerful solar flare. The effects these solar events had on the radio signals behaved as expected, and we were able to gain further insight into how radio signals are affected at USU.

Experiment date: January 2, 2023 – March 31, 2023

Report submitted: April 21, 2023

Introduction

Radio communication, before satellites, was the primary form of communication over long distances, and is still argued to be the most reliable form of communication. It is important to understand how these signals can be affected to maintain that reliability.

This research will focus on observing radio communications from USU campus through various parts of the world. By observing the data, we can deduce some ways in which radio communication can be disrupted, mainly regarding solar activity.

Theory

Sound waves are composed of many different wavelengths and frequencies. Radio communication uses the range called high frequency (HF) waves to communicate. HF ranges from about 3 to 30 MHz. (Fig. 1).

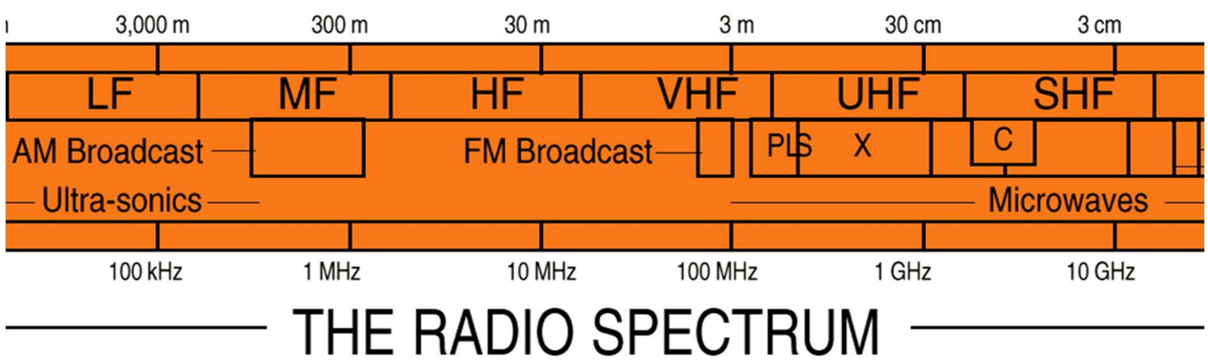

Figure 1. Radio spectrum with accompanying wavelength and frequencies. From [1].

The ionosphere is an essential component of long-distance radio communication due to its composition. Depending on conditions it can either enhance or degrade communication links.

The ionosphere is made up of layers due to the density of particles and ionization that occurs. Radio waves interact with these layers via absorption or refraction.

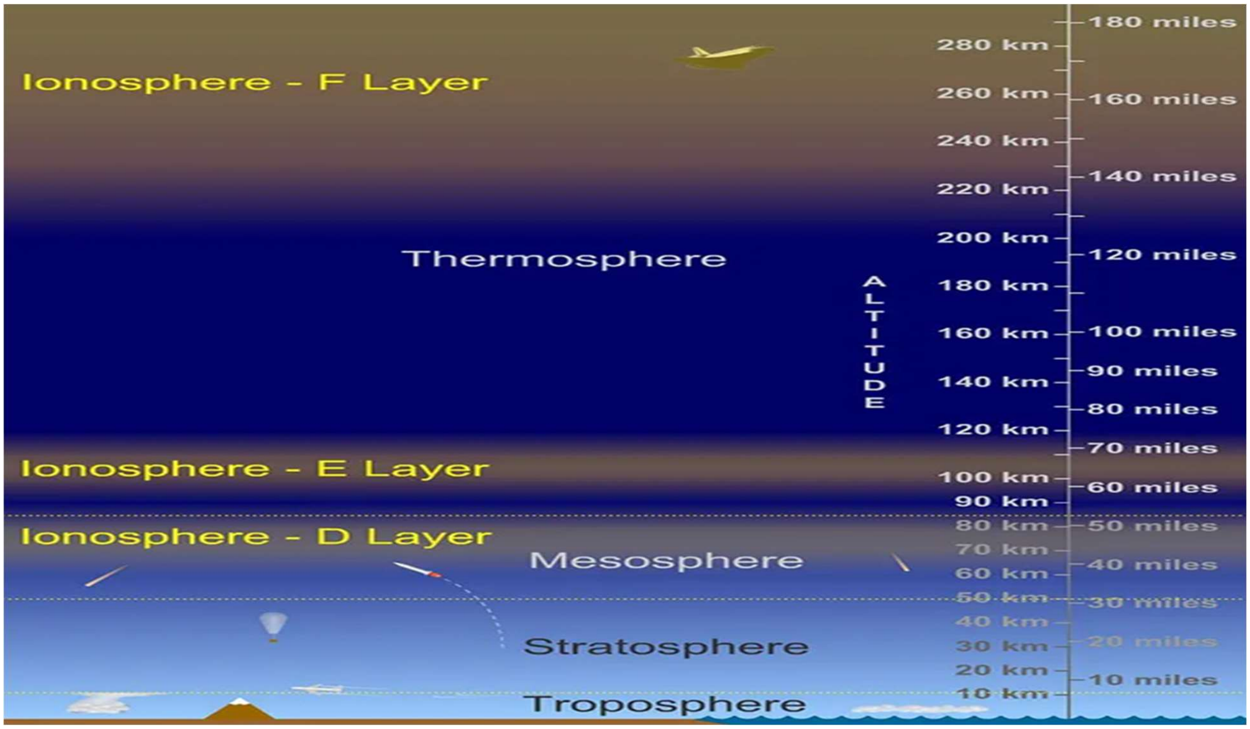

Figure 2. Image showing the various layers of the ionosphere. From [2].

D Region: The lowest region of the atmosphere that is the densest with regards to all particles, but the least dense when it comes to free electrons and ions. Due to this high particle density, many of the waves that pass through it get absorbed. This region is mostly used for low frequency, short range communication (3).

E Region: This region is the lowest region that can be used for long range communication. In this region, solar radiation and meteors can affect ionization which then alters the efficiency of the waves that pass through it (3).

F Region: This region has the highest electron density, but lowest overall particle density. Due to this, this region excels at reflecting radio waves and has the greatest use for long range communications (3).

Equipment

TABLE 1. List of equipment.

Equipment
Radio Antennae built on USU Research building
Radio Receiver to receive signals

Procedure

We monitored an international beacon network consisting of 18 stations across 5 HF bands. We focused our efforts on two of those stations on 2 bands. The stations are 4U1UN in New York and VE8AT in Inuvik, and the bands are 14 and 18 MHz (Fig. 3).

These two beacons were chosen due to 4U1UN being near similar latitude from the USU campus, as well as the beacon VE8AT being near similar longitude as the USU campus. Higher latitudes tend to be affected to a greater degree by solar activity. This allows for some ability to track discrepancies due to solar activity more effectively.

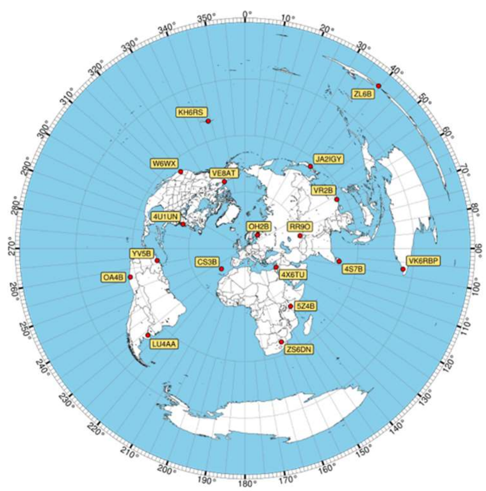

Figure 3. Beacon networks across the globe. From [4].

The data will be collected by our receiver continuously over the months of January, February, and March. We will track the signal to noise ratio for both beacons and both frequencies.

Results

We will look at a “quiet” day, meaning a day that has minimal solar activity.

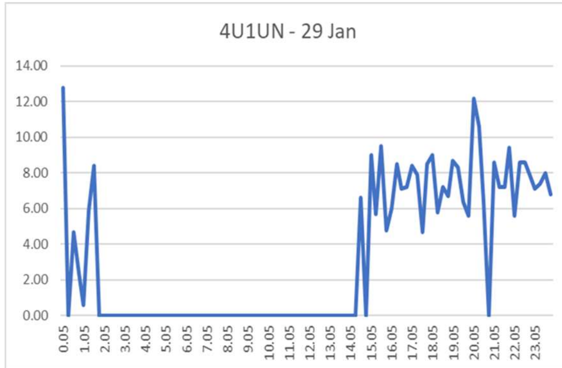

Figure 4. "Quiet" day from beacon 4U1UN.

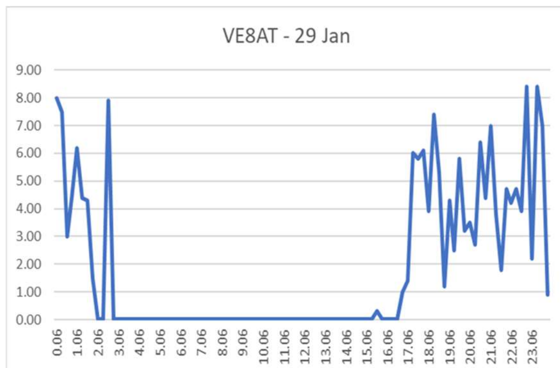

Figure 5. "Quiet" day from beacon VE8AT.

Figures 4 and 5 show two important time-related dependencies. The most obvious is a day/night variation demonstrating the dominant effect the sun has on the ionosphere. The other is a daytime variation that captures more subtle changes in propagation conditions throughout the day.

Figures 6 and 7 show the effect of high solar activity due to solar energetic proton (SEP) events. Proton events may cause a phenomenon as a form of geomagnetic storms. These storms can greatly disrupt radio communication, especially as you get to higher latitudes. What is expected is that the VE8AT beacon will show different activity than a “quiet” day but the 4U1UN beacon will remain relatively unchanged.

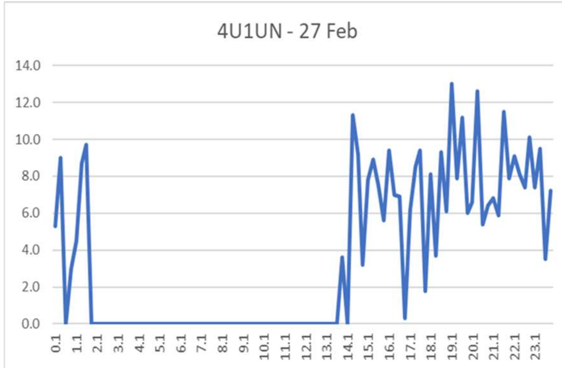

Figure 6. Signal received on the day of a geomagnetic storm from beacon 4U1UN.

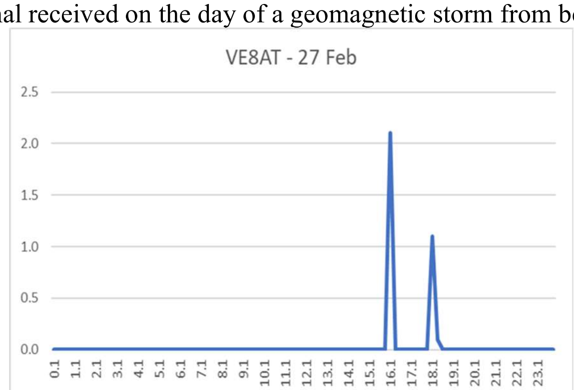

Figure 7. Signal received the day of a geomagnetic storm from beacon VE8AT.

As expected, the beacon network along similar latitude lines as USU exhibited normal behavior while the beacon network at a much higher latitude showed almost no signal received for the whole day.

Another phenomenon caused by solar activity that has the potential to disrupt radio communications are solar flares. Solar flares vary greatly in magnitude and follow along the periods of the solar cycle. Flares disrupt radio communication to a lesser degree than proton events. Flares generally only last for periods of an hour or two whereas proton events may last much longer.

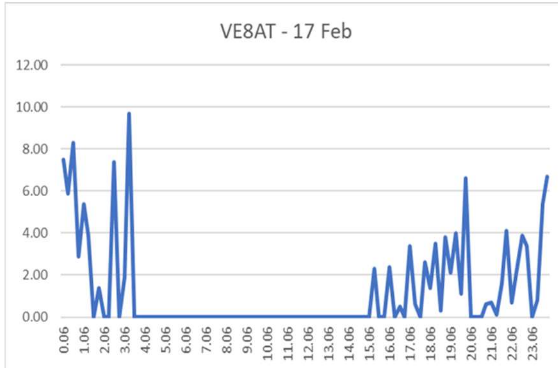

Figure 8. Day capturing solar flare with beacon VE8AT.

We were fortunate to gather data during a significant solar flare. On February 17, 2023, an X2-class solar flare was observed. Maximum energy occurred at about 20.16 UTC. Figure 8 shows the effects of that flare on HF communications.

Because the energy released by a solar flare travels at near the speed of light, their effects are felt on Earth within minutes and usually last for a short time. Only that portion of Earth pointed toward the Sun during the flare is affected.

As expected, the signal is received before the flare starts but cut off as the flare hits it's maximum energy. These results provide further evidence of the disruption caused by solar activity and by monitoring these phenomena.

For more information about solar flares and SEP events, see appendix.

Summary

The results from this research allow us to see some real effects that solar activity has on high frequency radio communications. More knowledge of these effects can improve the reliability of radio communication that it is known for.

Moving forward future experiments would be to look closely at the other beacon networks around the globe to see how the different locations vary with the signal.

Being able to measure the level of ionization in the ionosphere would also give great insight into how the radio signals behave around USU campus.

Supplementary Materials

The supplementary materials for this report may be found in the file lab1-data.zip, submitted to Canvas with this report. Movies of particle trajectories and the Python tracking program used to analyze them may be found in that archive. See Table 2 for a summary of the archive file contents.

TABLE 2. Supplementary materials in "Research_HF Radio.zip".

Filename	Content
First Month Data Summary.docx	Summary of the first month of data
Lab Notebook.pdf	Scanned lab notebook pages
Monthly Data Averages.xlsx	Average SNR values each month of data
Report.docx	Word document of report
Signal vs. Noise.docx	Document discussing signal and noise
Week 1 Data.xlsx	Raw week 1 data
Week 2 Data.xlsx	Raw week 2 data
Week 3 Data.xlsx	Raw week 3 data
Week 4 Data.xlsx	Raw week 4 data
Week 5 Data.xlsx	Raw week 5 data
Week 6 Data.xlsx	Raw week 6 data
Week 7 Data.xlsx	Raw week 7 data
Week 8 Data.xlsx	Raw week 8 data
Week 9.xlsx	Raw week 9 data
Week 10.xlsx	Raw week 10 data
Week 11.xlsx	Raw week 11 data
Week 12.xlsx	Raw week 12 data

Acknowledgments

T.L. wishes to thank Dr. David Smith for his guidance and mentorship along with the use of his equipment.

References

[1] See https://www.transportation.gov/pnt/what-radio-spectrum for original image; accessed 6 February 2023.

[2] See https://scied.ucar.edu/learning-zone/atmosphere/ionosphere for original image; accessed 6 February 2023.

[3] *Center for Science Education*. The Ionosphere | Center for Science Education. (n.d.). Retrieved October 21, 2022, from https://scied.ucar.edu/learning-zone/atmosphere/ionosphere

[4] See https://monitorstation.ccms-best.nl/maps.html for original image; accessed 6 April 2023.

[5] *HF Radio Communications*. HF Radio Communications | NOAA / NWS Space Weather Prediction Center. (n.d.). Retrieved April 21, 2023, from https://www.swpc.noaa.gov/impacts/hf-radio-communications

[6] *Solar flares (radio blackouts)*. Solar Flares (Radio Blackouts) | NOAA / NWS Space Weather Prediction Center. (n.d.). Retrieved April 21, 2023, from https://www.swpc.noaa.gov/phenomena/solar-flares-radio-blackouts

Appendix

SEP events such as radiation storms or geomagnetic storms cause changes in the earth's magnetic field. Protons that reach the earth are guided by the earth's magnetic field where they collide mainly at the north and south poles. These protons affect the ionosphere similarly to solar flares and can block radio signals depending on the strength of the event (5).

Solar flares are sudden bursts of electromagnetic energy that travel to earth at the speed of light. This increased radiation, depending on the strength of the flare, causes increased ionization of the D layer of the ionosphere which results in HF radio communication to degrade as it travels through this layer causing radio blackouts (6).