Early Results from the 2023 Eclipse Medium Wave Recordings

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Outline

- This talk will be about data generated by HamSCI volunteers at 14 sites in North America and Europe recording the entire medium wave AM broadcast band using software defined radios.

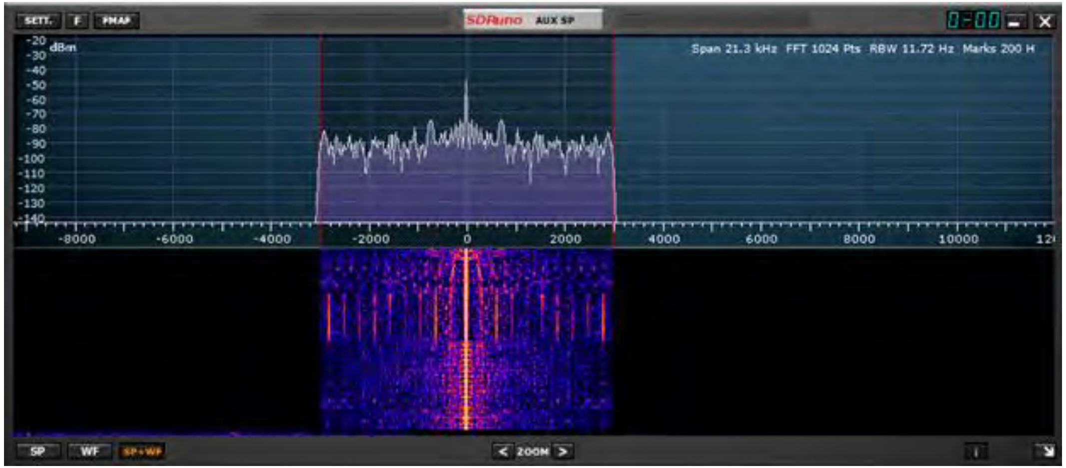
- The data from these recordings has now been pre-processed to allow researchers to easily find evidence of eclipse effects upon the carrier signals of medium wave broadcasters by using visual examination.

- Examples will be given of how this data might tell researchers more about these eclipse effects.

Introduction

Unlike the short duration communications found on the amateur radio bands, medium wave (MW) AM broadcasters, assigned between 525 and 1705kHz, provide continuous signals, many for 24 hours a day.

Their carrier frequencies are like steady RF beacons.



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Introduction

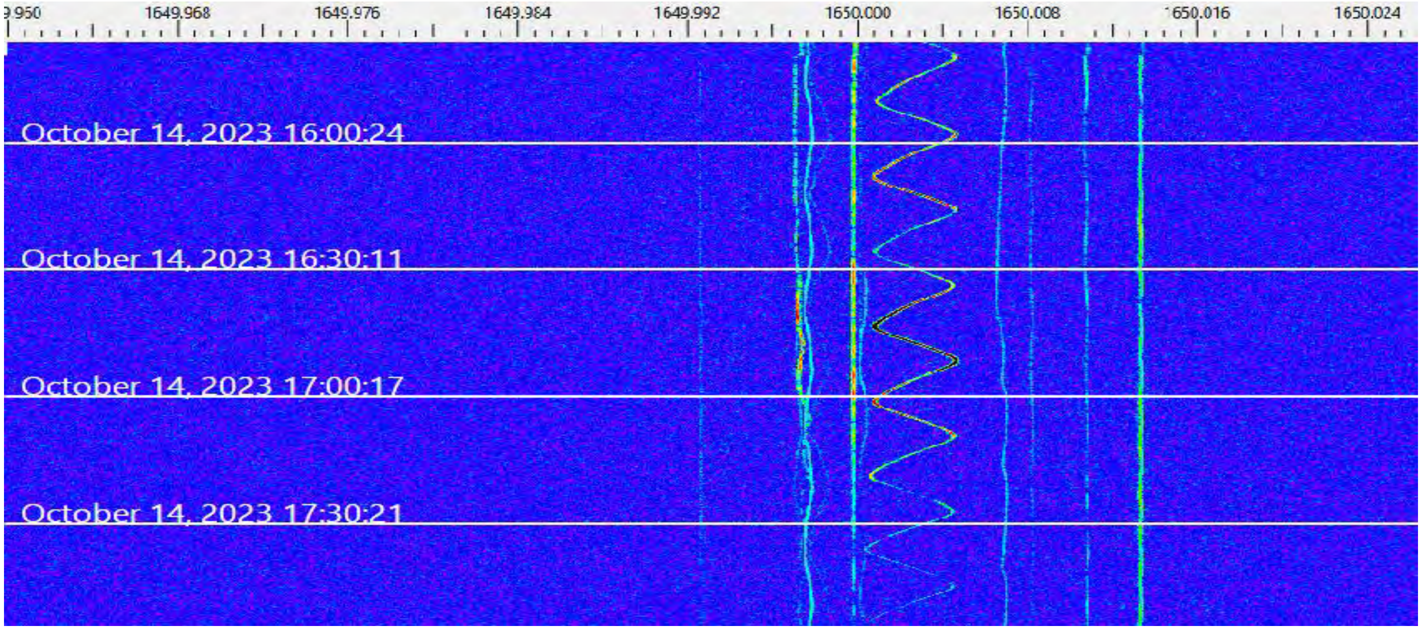
- Any changes in that beacon's amplitude or frequency at a receiver are likely to be caused by changes in the path between transmitter and receiver.

- During a solar eclipse, the brief period of darkness along the path of the eclipse can allow such signals to temporarily travel much further than they normally would in the daytime.

- Software defined radios (SDRs) can record the entire medium wave broadcast band, and by using suitable software, the resulting files can allow us to visualize the propagation induced changes that these carriers undergo over time, including changes in signal strength and shifts in frequency of each carrier.

Introduction

An example output from visualization software is shown below, for 1650 kHz, as logged during eclipse enhancement in Phoenix, AZ by Burke Baumann KF7NP.



Introduction

During the 14 October 2023 annular solar eclipse, HamSCI organized 13 volunteers at 14 sites in Canada, USA, Mexico and Portugal to record the entire medium wave band using software defined radios

Introduction

- All 14 sites produced recordings during the eclipse
- 12 sites also included data from local sunrise (LSR) and/or local sunset (LSS)
- 12 sites also recorded data from the same time as the eclipse period on another date in order to provide a reference of a normal day's reception conditions
- 6 sites produced data using an SDR locked to a frequency standard that was disciplined using GPS signals. Three others included a signal from a frequency standard in their data recording.
- 10 sites recorded using computers that had their clocks updated using Network Time Protocol (NTP)

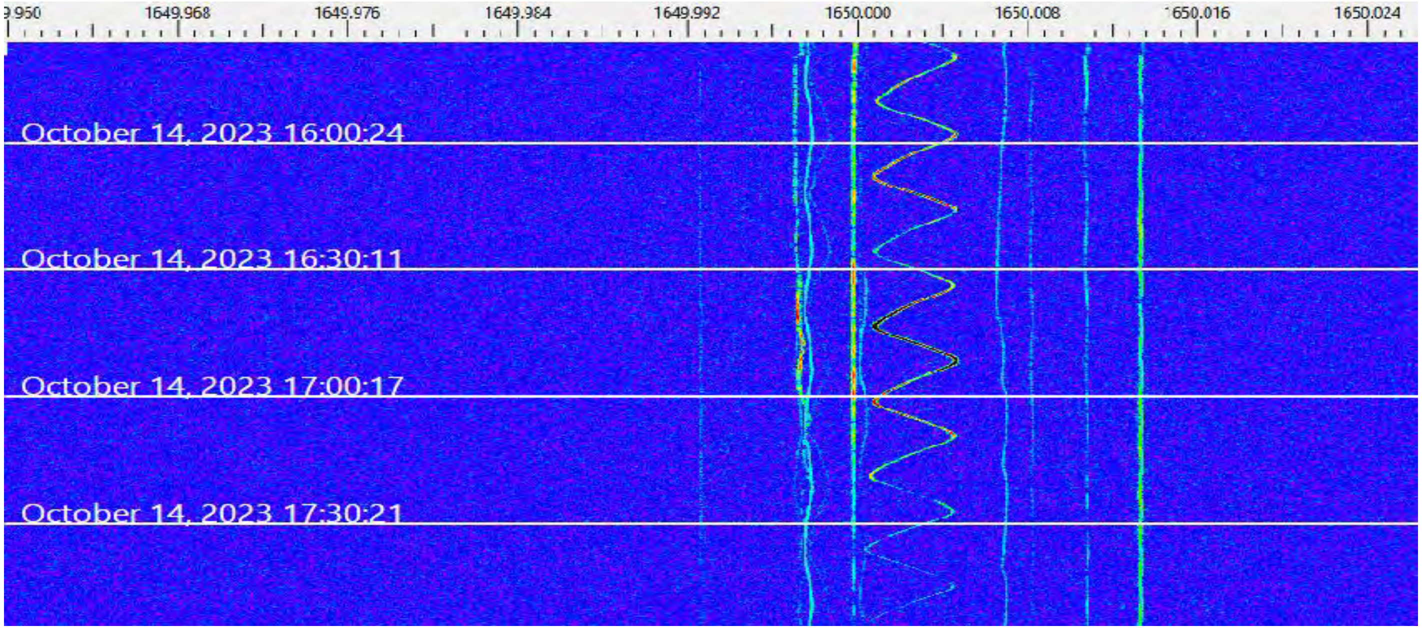
Introduction

Since the eclipse:

- **All 10TB of medium wave data has been gathered and archived.**
- **Preliminary processing has been done, using Carrier Sleuth, an inexpensive commercial software package.**
- **All signal strength data from each participant is now available to 0.1Hz resolution over an 80Hz span around each broadcast channel.**
- **In addition, for all broadcast channels, and from every participant, useful visualization of signal variations during the eclipse is now available, as well as for all other time periods recorded at each site.**

(initial) Analysis

Using Carrier Sleuth for each participant's data set, it was possible to scan through each of the 117 channels of the AM broadcast band, searching for unusual carriers appearing during the eclipse time period, and then fading away again.



(initial) Analysis

It was arbitrarily decided that a carrier that increased in strength by at least 10dB during the duration of the eclipse at that site would be deemed to have been influenced by the passage of the moon's shadow.

- Did our participants, other than KF7**NP**, see the eclipse affect their normal daytime reception?

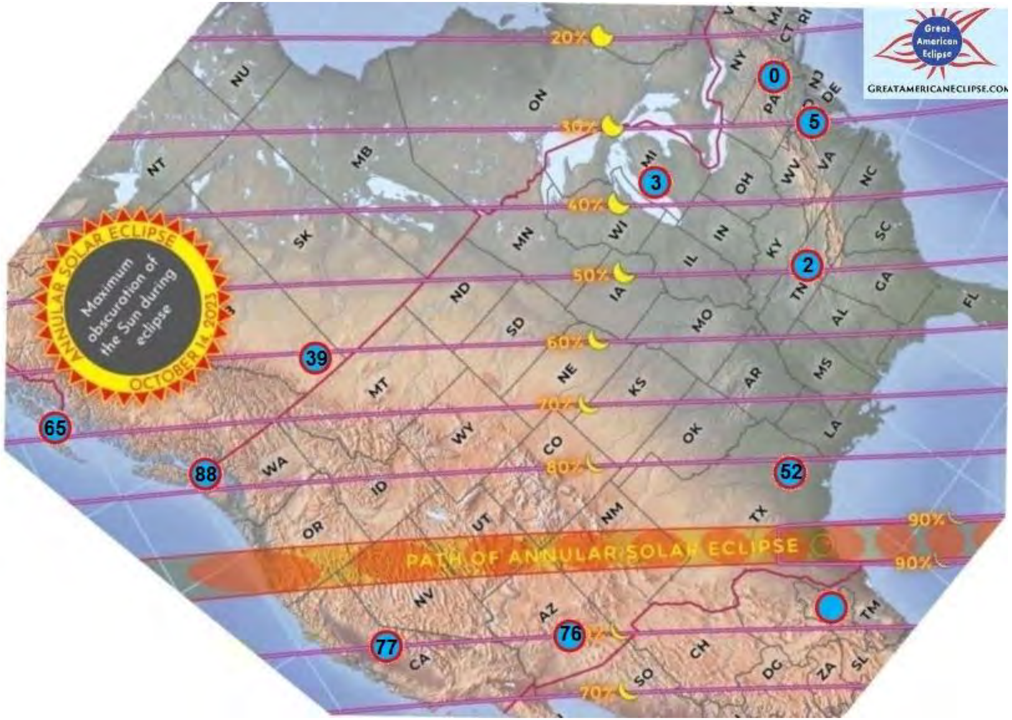
  - Six sites indeed reported that different stations from those normally received in the daytime appeared during the eclipse.

  - However, others did not.

Looking back at our map of participants, what locations were influenced most by the passage of the eclipse?

(initial) Analysis

- *those who saw little eclipse enhancement were in locations that exhibited 50 % totality or less.*



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(initial) Analysis

It will be interesting to see if this rule of thumb obtains during the upcoming total solar eclipse on 8 April—many of the same monitors will be taking part, but the path of 2024 eclipse will favor those in the eastern USA considerably more than in the west.

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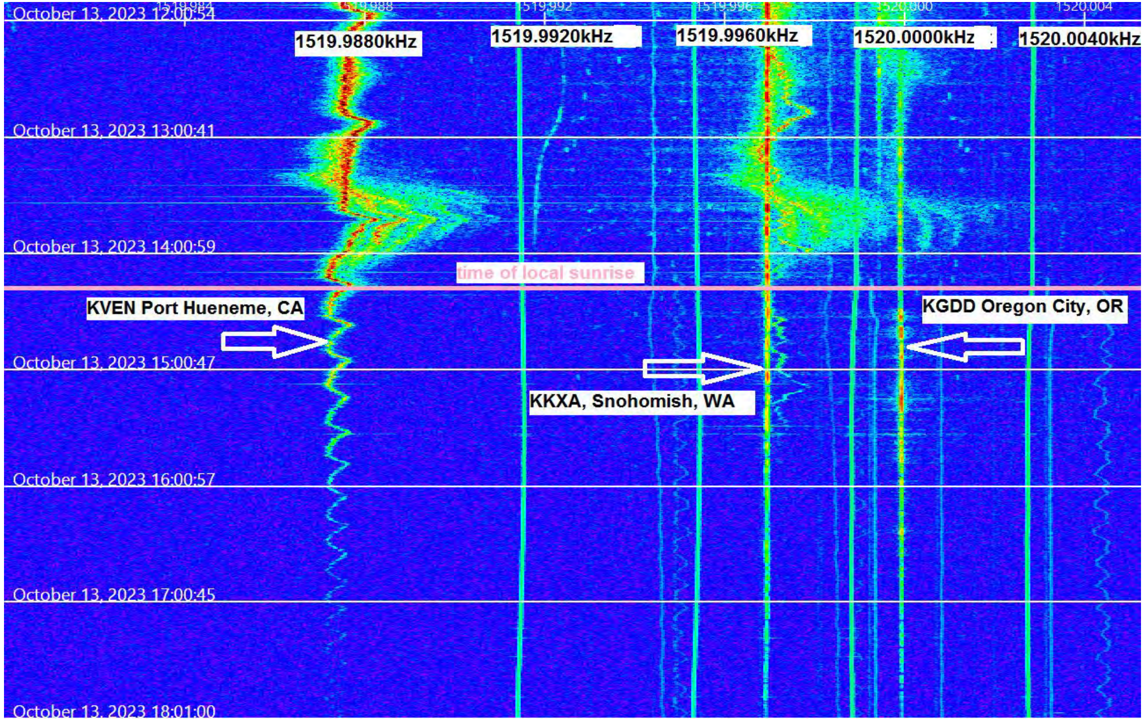
Visualizing the recorded data

Once the channels affected by the eclipse had been identified, the Carrier Sleuth processing software could allow us to get a good view of how any signal enhancement progressed during the eclipse. The following visualization of station carriers on 1520kHz recorded near Sacramento, CA by from Richard Cook, KE6EE, is an example.

- the recording included both the time period of the annular eclipse, 1505 to 1743UTC (8:05 AM to 10:43 AM PDT) as well as the period during the ionospherically active period around local sunrise at 1413 UTC (7:13 AM PDT)

- Richard also recorded the same time period on 13 October 2023 to provide a comparison

October 13, 2023 observations



- before local sunrise, carriers were shifted and spread out by the effect of the rising sun
- carrier strengths declined rapidly after local sunrise

(KGDD's apparent rise in signal strength after sunrise was due to it having switched to higher day time power at 1430UT)

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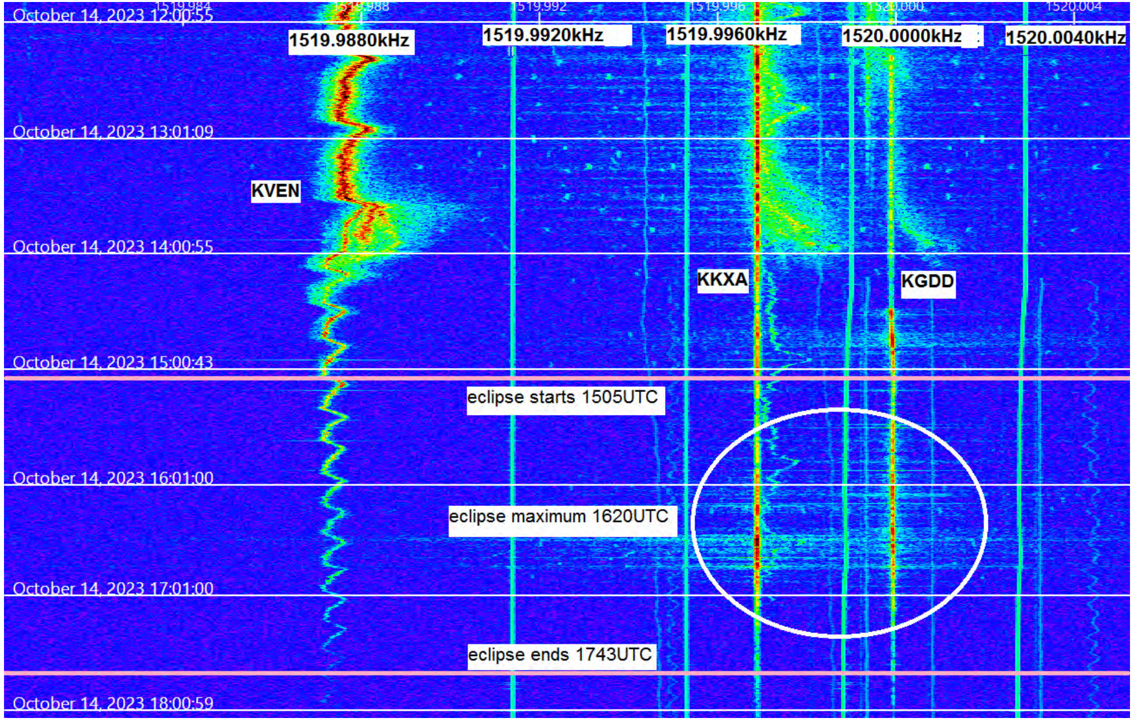
October 14, 2023 observations



KKXA and KGDD carrier strength increased and then decreased during the course of the eclipse.

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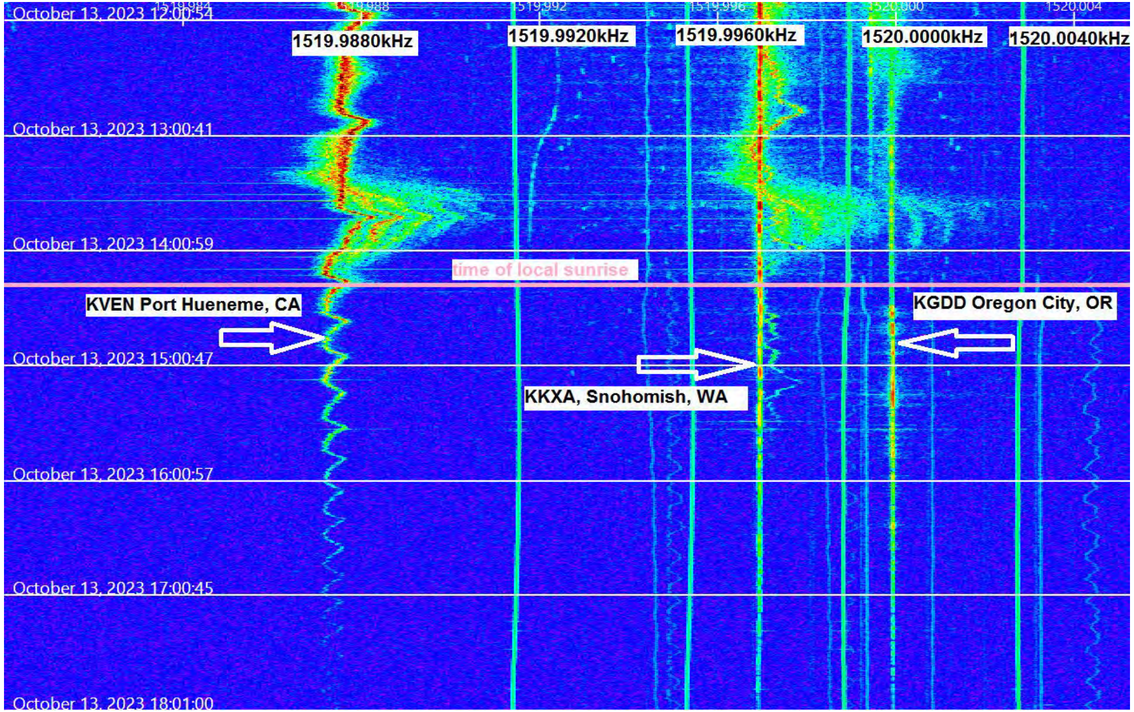
October 13, 2023 observations



KKXA and KGDD carrier strength increased and then decreased during the course of the eclipse.

On October 13th, however, those signals had gradually faded away during that time period.

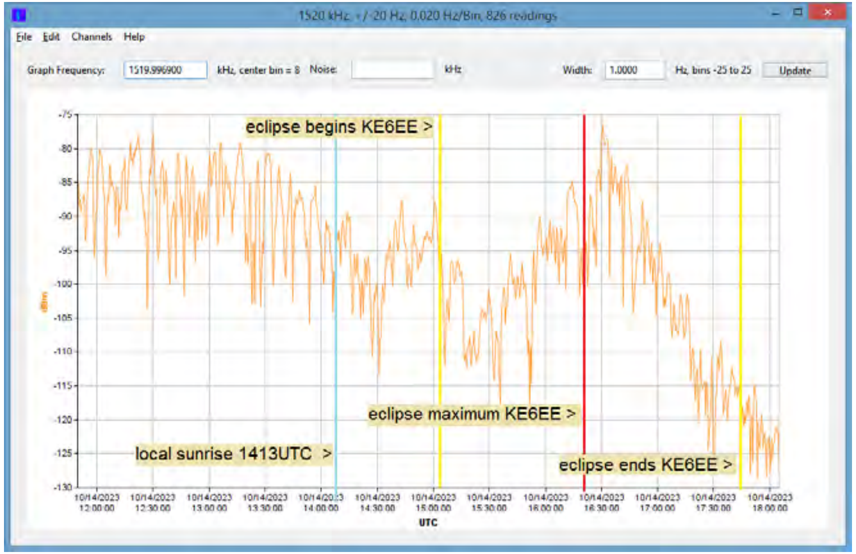
Let's compare KKXA's signal strength on those two mornings---

KKXA signal strengths on October 13th and 14th, 2023, at KE6EE

no eclipse

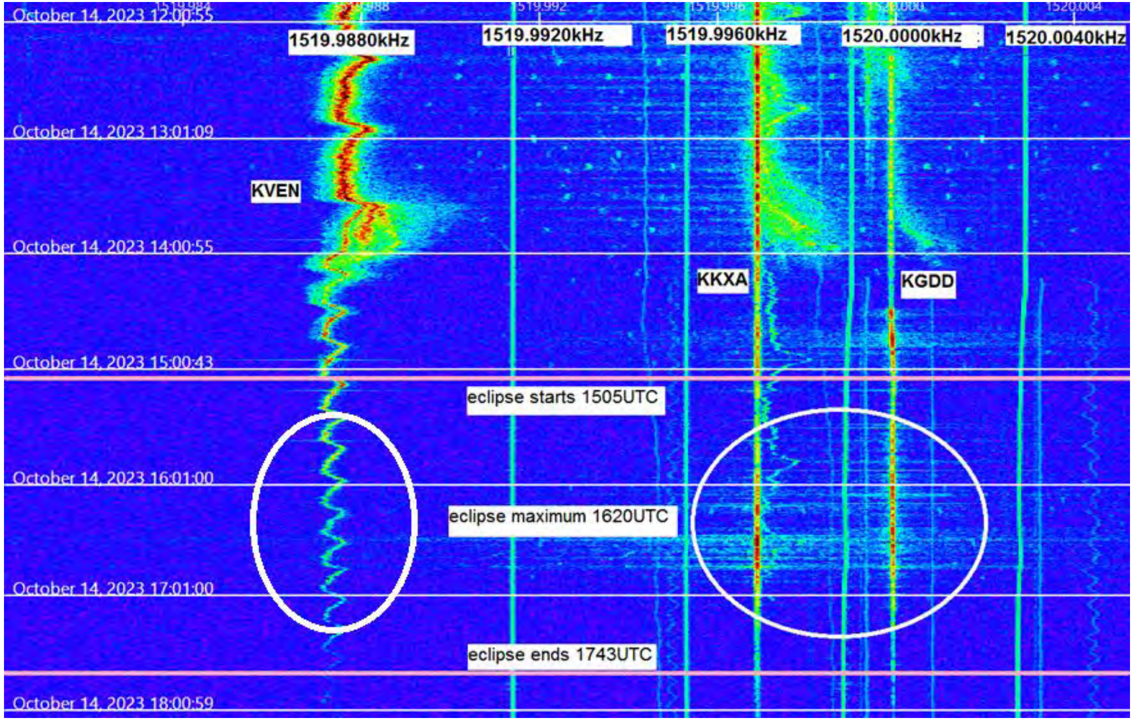
annular solar eclipse

October 13



October 14

October 14, 2023 further observations



KKXA and KGDD carrier strength increased and then decreased during the course of the eclipse.

However, there seemed to be no effect on the carrier strength of KVEN.

What explains the difference?

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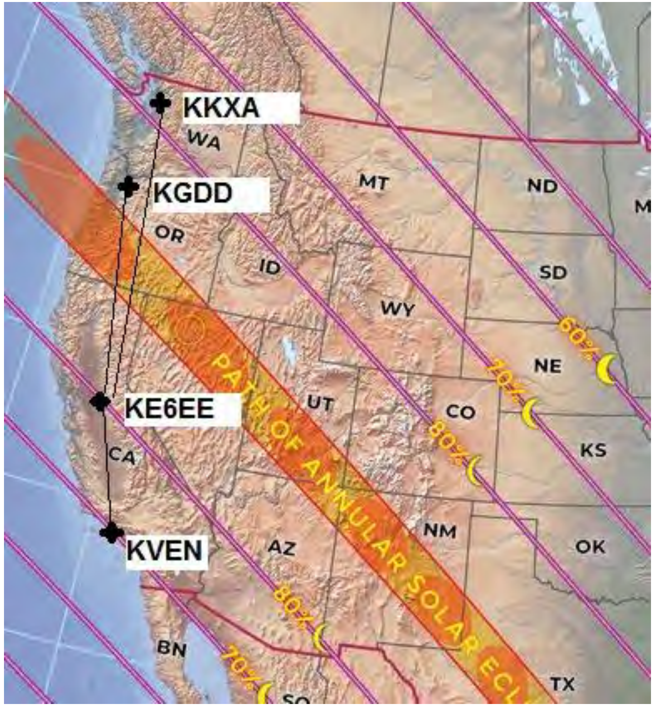
transmitter and receiver locations

The KKXA, KGDD transmitters and KE6EE receiver were all within the 80% obscuration zone, and *the paths from transmitters to receiver crossed the path of the eclipse*

The path from the KVEN transmitter to the KE6EE receiver *did not cross the path of the eclipse*, and KVEN was at 70% obscuration



derived from greatamericaneclipse.com graphic

What science could this data support?

A couple of HamSCI science objectives might be supported using these SDR recordings:

- Is eclipse ionospheric response symmetric with regard to onset and recovery timing?
  - Could the rate of buildup versus decay of signal strength of target signals indicate differing ionospheric response as the eclipse progresses?

- How similar is the eclipse effect on propagation to that of the daily dawn and dusk terminator passage?

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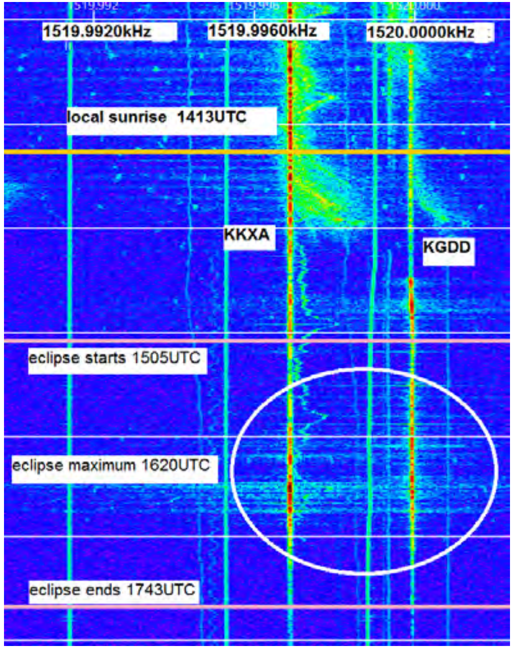
What science could this data support?

- **How similar is the eclipse effect on propagation to that of the daily dawn and dusk terminator passage?**

Just visualizing the carriers in KE6EE's 1520 kHz data shows that:

- **Spectral spreading and some shift of frequencies of the carriers during local sunrise occurred, as well as declining signal strength.**
- **During the eclipse, only the amplitude of the carriers increased and then decreased as the eclipse progresses.**



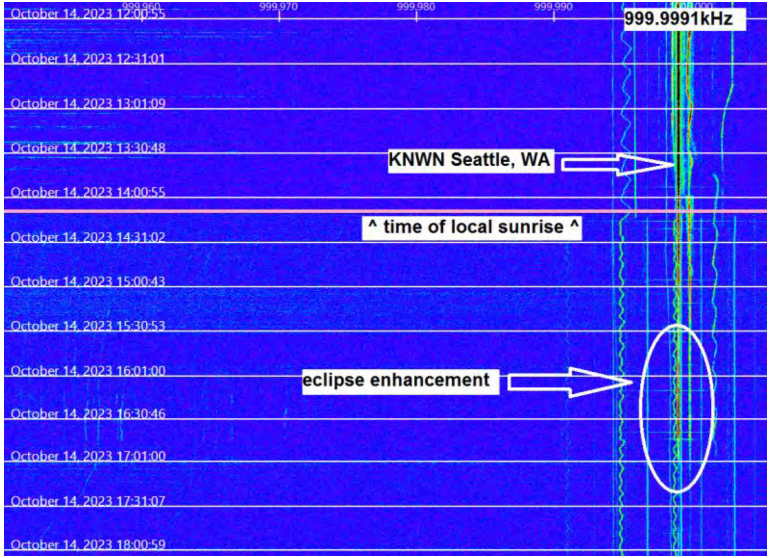
What science could this data support?

- **How similar is the eclipse effect on propagation to that of the daily dawn and dusk terminator passage?**

However, the recording of 1520kHz is just one example.

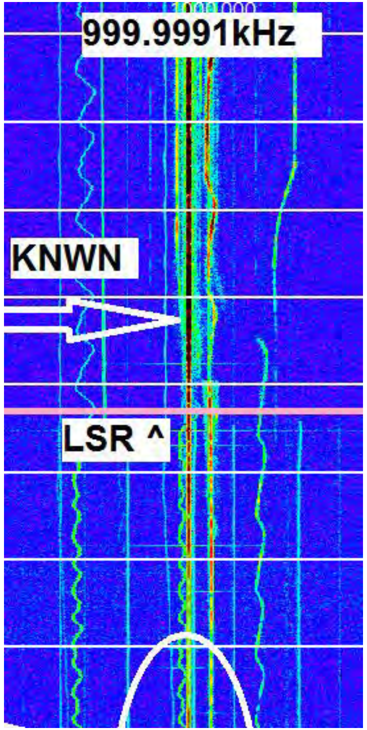
- **If we look at 1000kHz in the same data set (KNWN from Seattle), then there is very little difference in carrier characteristics during local sunrise, and during the eclipse enhancement period**

- **Note that the MW band has a 3:1 frequency span, and comparing 1000kHz to 1520kHz is like comparing 20m amateur band propagation to 15m propagation**



What science could this data support?

- How similar is the eclipse effect on propagation to that of the daily dawn and dusk terminator passage?



Close examination of KNWN's carrier may show a small amount of spectral spreading, but it is far less than that seen on KKXA's carrier on 1520kHz.

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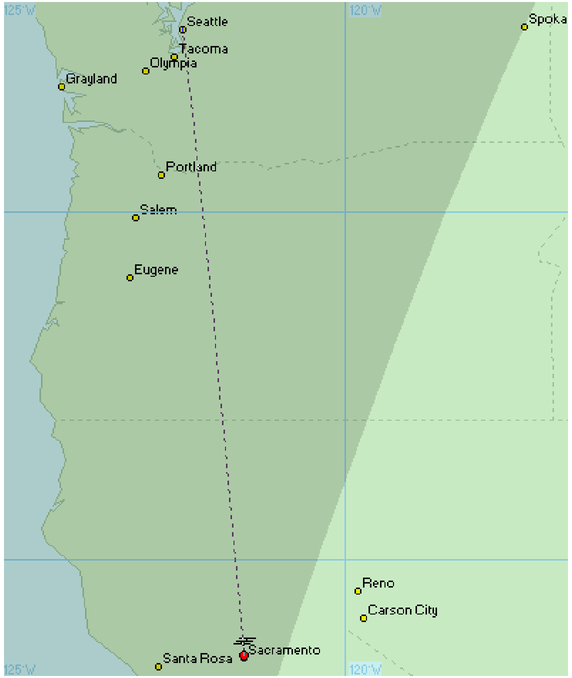
What science could this data support?

- **How similar is the eclipse effect on propagation to that of the daily dawn and dusk terminator passage?**

Beyond frequency differences, perhaps we also need to think about :

- **the signal path from transmitter to receiver relative to the angle of the sunrise or sunset terminator**

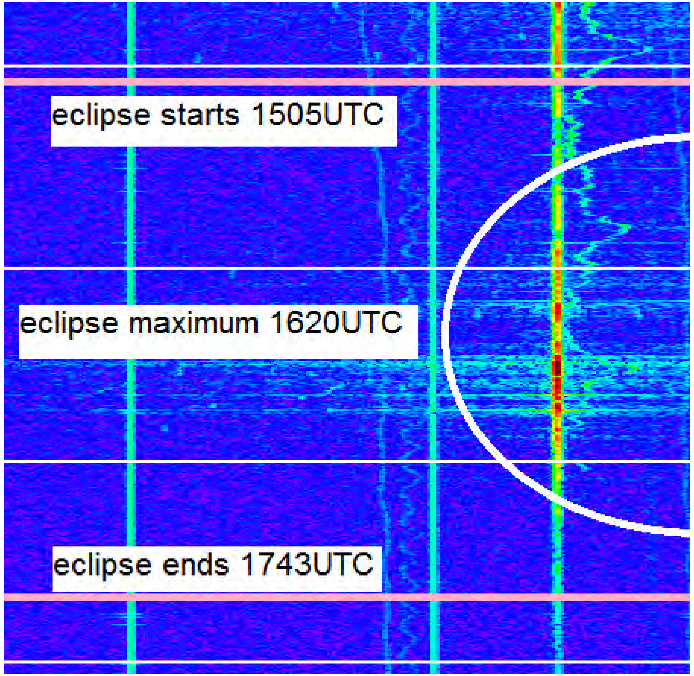
- **the angle at which the signal path crosses the path of the eclipse**



What science could this data support?

- **Is eclipse ionospheric response symmetric with regard to onset and recovery timing?**

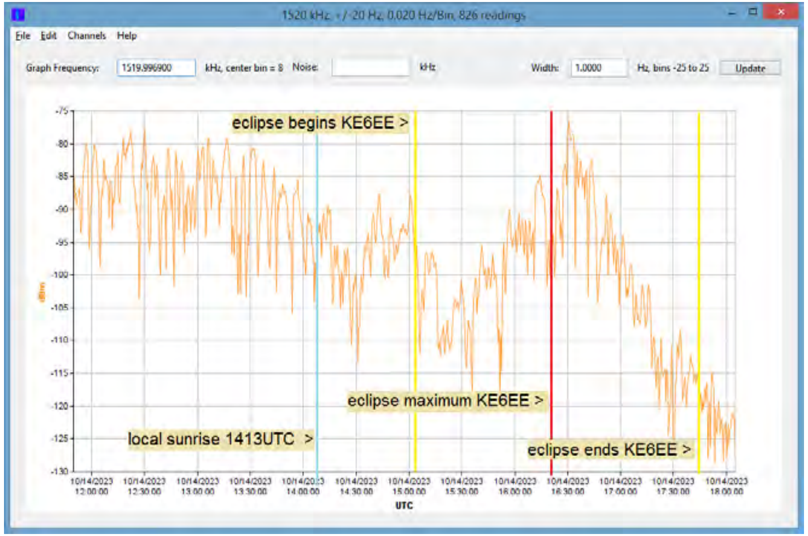
Visualization can give a rough idea of the rate of increase and decay of the carrier signal strength during the eclipse.



What science could this data support?

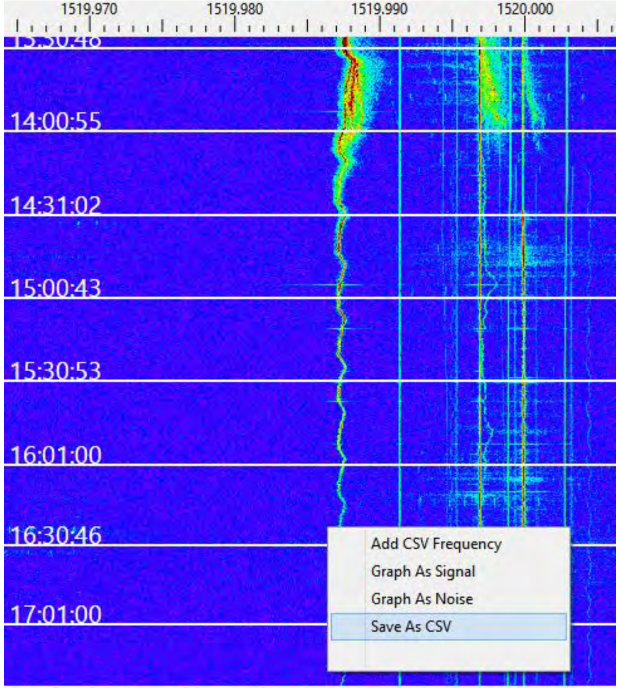
- Is eclipse ionospheric response symmetric with regard to onset and recovery timing?

And, Carrier Sleuth can generate a graph of signal strength vs. time for a quick first look, but it's just a snapshot.



What science could this data support?

- **Is eclipse ionospheric response symmetric with regard to onset and recovery timing?**



However, the same software can deliver CSV files of signal strength vs. time for a 0.1Hz slice of spectrum, which can allow us to start processing the data in earnest.

1	Timestamp	999.9991	1159.9999	1519.9970	kHz
2	2023-10-14 03:55:51	-73.8203	-58.78125	-84.13281	
3	2023-10-14 03:56:04	-73.7266	-59.28125	-84.64063	
4	2023-10-14 03:56:17	-73.7891	-60.11719	-83.71875	
5	2023-10-14 03:56:31	-73.6875	-60.86719	-85.46875	
6	2023-10-14 03:56:44	-75.5781	-61.71094	-86.10938	
7	2023-10-14 03:56:58	-77.3984	-61.91406	-86.53906	
8	2023-10-14 03:57:11	-79.7734	-62.92188	-86.5625	
9	2023-10-14 03:57:24	-83.6875	-64.8125	-85.32813	
10	2023-10-14 03:57:38	-88.1875	-65.89844	-85.3125	

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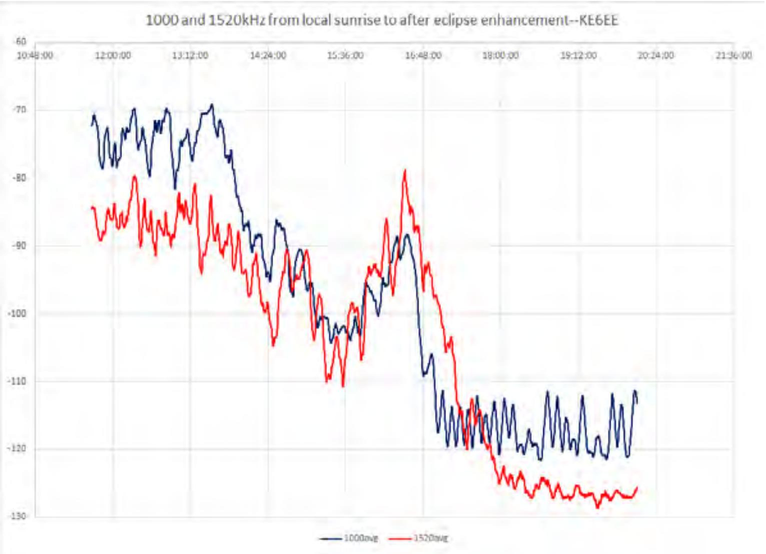
What science could this data support?

- **Is eclipse ionospheric response symmetric with regard to onset and recovery timing?**

The CSV file can then be ported into an Excel spreadsheet or other software for further analysis.

Here you can see a chart created from KE6EE's raw data for both KNWN-1000kHz, and KKXA-1520kHz.



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What science could this data support?

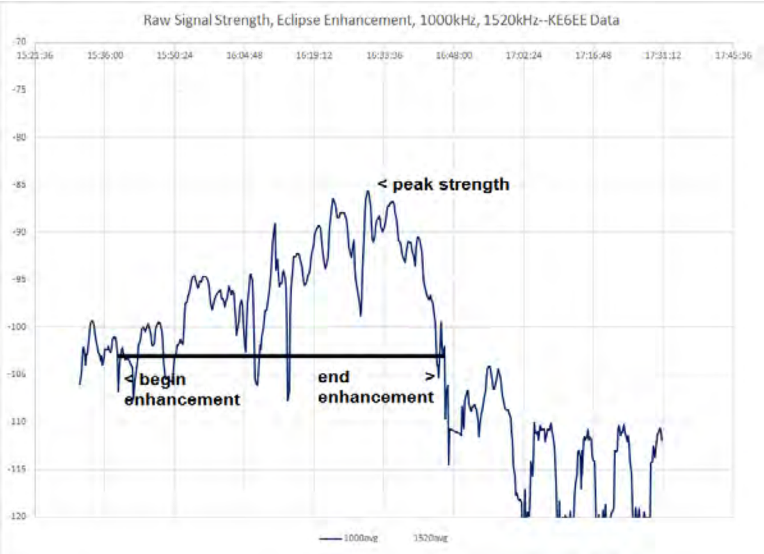
- **Is eclipse ionospheric response symmetric with regard to onset and recovery timing?**

And now, KNWN-1000’s signal alone, zoomed in to show the beginning and end of the enhancement.

In Excel, it is straightforward to get the slope of this rise in signal strength vs. time, followed by the slope for the decay in strength.

- slope for increase = 0.26 dB / minute
- slope for decay = -0.87 dB / minute

➢ ratio of decay in strength to increase = 3.35



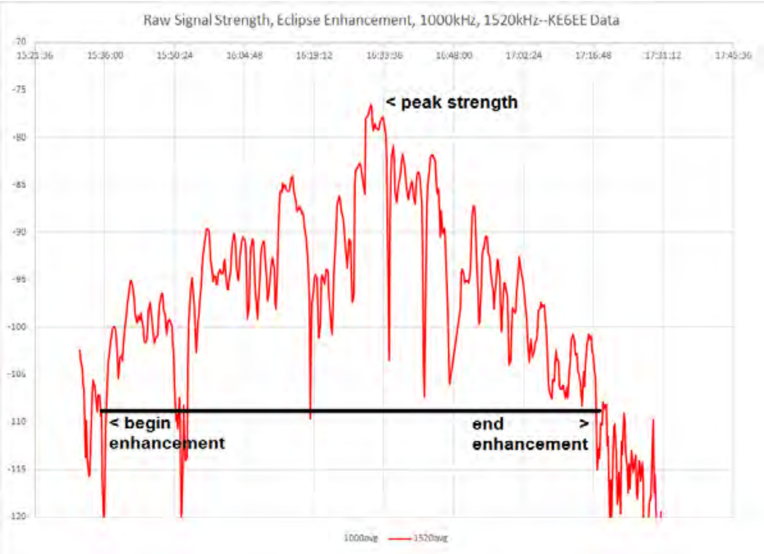
What science could this data support?

- **Is eclipse ionospheric response symmetric with regard to onset and recovery timing?**

Let's repeat the exercise for KKXA's signal on 1520kHz.

- slope for increase = 0.31 dB / minute
- slope for decay = -0.56 dB / minute

➢ ratio of decay in strength to increase = 1.81



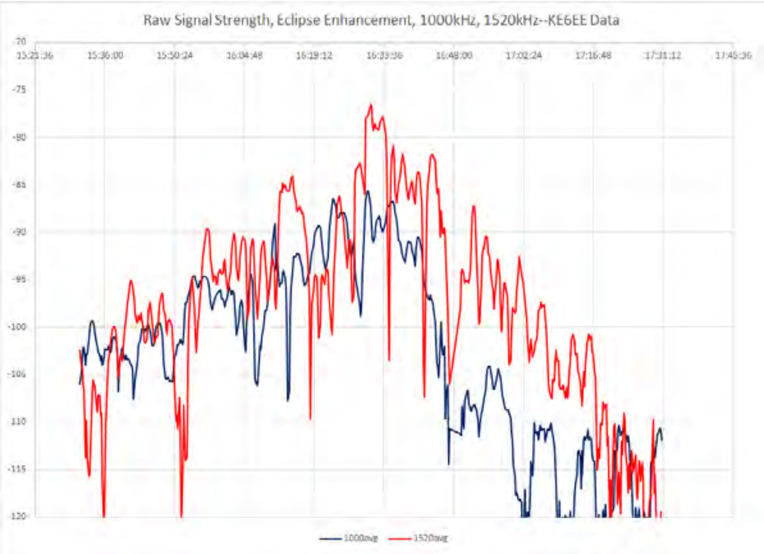
What science could this data support?

- **Is eclipse ionospheric response symmetric with regard to onset and recovery timing?**

The 1000kHz rate of decay of -0.87 dB / minute is considerably greater than the -0.56 dB / minute of 1520kHz.

- This is quite visible in a comparative graphical representation of the two signals' strength.

Once again, the effects of the eclipse seem to have depended upon the frequency of the received signal.



What science could this data support?

"Once again, the effects of the eclipse seem to depend upon the frequency of the received signal"

- **Of course, that's from one data set, looking at two received signals of differing frequency, but transmitted from essentially the same location.**
- **There were over 400 distinctive enhancements flagged in the fourteen data sets gathered.**
- **So…there's a lot more analysis to be done.**
- **And, in a couple of weeks, there will be more data to examine.**

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What's next? (other than the April 8th eclipse?)

In the analysis of KE6EE's recording, it was possible to identify the target carriers discussed here from the SDR recordings—they gave on-air identification with quite readable audio. Their transmitter locations are available in public databases.

However, for many of the carriers of interest in other recordings submitted, we may not have identifiable audio available in the SDR recordings.

- how can we find the locations of the transmitters associated with those fleeting carriers?

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What's next? (other than the April 8th eclipse?)

Many of the data sets submitted used GPS based reference signals to discipline the clock of the participants' SDRs.

- That means that the carrier frequencies observed should be accurate to ± 0.1Hz.

A subset of medium wave DXers archive the exact frequency of radio stations as an aid to identifying rare DX heard, as many broadcast stations are stable to 0.1Hz.

We are going to encourage such DXers to record a short period during the upcoming eclipse day, at the top of the hour (when stations are supposed to identify themselves), and to submit that SDR file as part of the HamSCI eclipse archive to aid in identifying these mystery carriers.

Conclusion

- **Data for the 2023 MW Recording Event was successfully recorded and archived from across North America as well as from Portugal.**

- **Initial pre-processing of this data has made it easy to examine this data for influences on MW broadcast carriers by the annular solar eclipse.**

- **Some HamSCI science objectives might be met with this data, and examples have been provided.**

- **Ways need to be devised to identify the origins of many of these enhanced carriers.**

- **No effort has been made to link these observations with possible ionospheric processes. That will be work for another day.**

Thank you.

and special thanks to the participants in the 2023 MW Recording Event:

Burke Baumann, KF7NP
Mike Boice, KW1ND
Manuel F. Caballero, XE2NNS
John Ciccolella, N3BE
Richard Cook, KE6EE
John Glover, W2QL
Carlos Nascimento, CT7AUS
James Niven
Nigel Pimblett, VE6TNF
Tim Tromp, KE8JFM
Bill Whitacre
Mark Whittington, AG5RT

as well as to Dave Pascoe, KM3T, and to the Thursday afternoon SEQP crew