April 2024 eclipse
the effect on transatlantic HF propagation

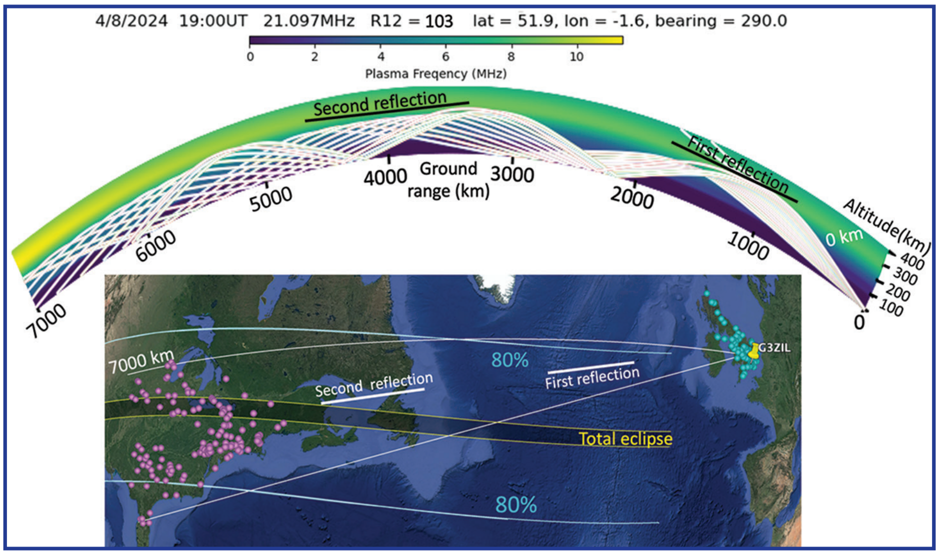

FIGURE 1: Top: ray-trace simulation of a transatlantic propagation path, heading 290° from Southampton at 21.097MHz at 1900UTC, showing landing spots from two-hop propagation spanning 4200km to 6000km. Bottom: a map showing the locations of the first and second ionospheric reflections, active WSPR UK transmitters, and North America receivers, on headings 282° to 298°. Also shown are the eclipse track and the zone 80% obscured.

The total eclipse on 8 April 2024 began over the eastern Pacific, traversed North America, passed over Newfoundland, and ended at sunset over the eastern Atlantic. Despite its seeming remoteness from the UK, this eclipse was a rare opportunity to assess the effects of a daytime dip in ionospheric ionisation on the well-used transatlantic propagation path.

Introduction

As with all eclipses, its timing and path were entirely predictable. That prior information led to a multitude of preparatory propagation studies across North America [1]. It also made me wonder whether the eclipse would affect the final hop of upper HF-band signals transmitted from the UK and received in North America. This article answers that question in three stages. In the first stage, I use the prior information alongside a ray-tracing propagation-path program to guide data collection. In the second stage, having obtained the results, I assess whether other propagation-affecting factors were at play. Finally, I present the results and draw conclusions.

Using prior information

It is good practice when planning an experiment around a rare natural event to investigate what might be expected. This helps ensure the data collected will prove useful and amenable to interpretation. It will also show where additional measurements may be required. Having used WSPR in previous propagation studies, it was my natural choice for the April 2024 eclipse.

The eclipse's track and timing were available on many websites [2], and .kml files for Google Earth showing the eclipse track were available from NASA [3] (see **Figure 1**). UK WSPR transmitters active on 14MHz to 28MHz on 8 April 2024 are shown in cyan. The receivers in North America, in magenta, are those that lie between headings 282° and 298° from my location in Southampton, UK. Most propagation paths from the UK to North America would pass over the zone with at least 80% of the Sun obscured, between the cyan lines in Figure 1.

Taking the mid bearing of 290° and 1900UTC for the eclipse over eastern North America, the next step was to obtain ray-trace simulations of HF-band propagation paths. I used the freely-available PyLap package [4]. A prior assumption was that the higher-frequency HF bands would be more affected as the critical frequency dropped owing to the ionisation dip. There also needed to be a good chance of the bands being open on eclipse day, and the days either side, given the forecast smoothed sunspot number of 103 for April 2024 [5]. PyLap ray tracing of the un-eclipsed ionosphere showed that 21MHz was likely to be open until after the eclipse had ended. Furthermore, the two-hop zone, Figure 1, covered highly-populated regions of New England, New York and the Atlantic states.

The ray trace showed that both first and second reflections would be within the eclipsed region. The earliest effect would be on the second reflection. The relative importance of the eclipsed ionosphere on reflections for the first and second hop could be gauged, roughly, with a simple metric: the product of the cosine of the solar zenith angle (SZA, the angle between the Sun and the zenith) and the eclipse obscuration factor [6]. Both of these factors were dependent on location and time. The calculations take representative locations of 54.3°N 20°W for the first reflection, and 49.8°N 59.6°W for the second. **Figure 2** shows that the eclipse's effect on the first reflection would be small, as the Sun would be low in the sky. In contrast, there would be a substantial, transient, drop in solar input over the second reflection.

Factors that may have affected results

The task of identifying and attributing a change in propagation to a single cause, here the total eclipse, may be confused, or possibly overshadowed, by other factors. Hence a systematic assessment of those other factors is important. The most likely were the following.

First, a solar flare could have led to a radio blackout. Luckily, the largest X-ray solar flare on eclipse day was minor, class C1, and at 0315UTC, well before the eclipse [7].

Second, geomagnetic conditions might have been disturbed. As it turned out they were quiet, the average planetary geomagnetic disturbance

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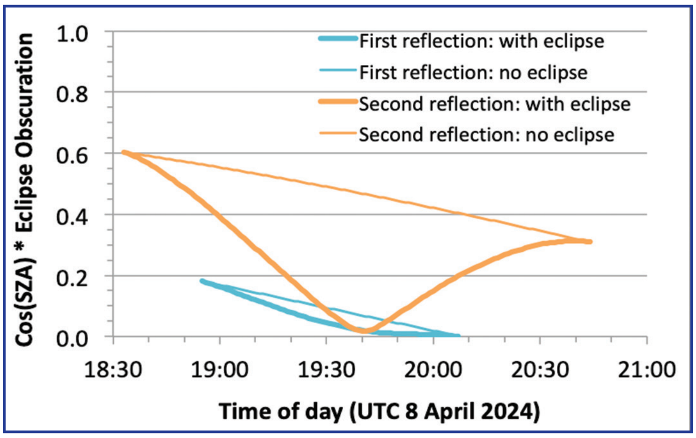

FIGURE 2: A simple metric, the product of the cosine of the solar zenith angle and the eclipse obscuration function, that illustrates the likely perturbation to the solar input at the times and locations of the first and second reflections.

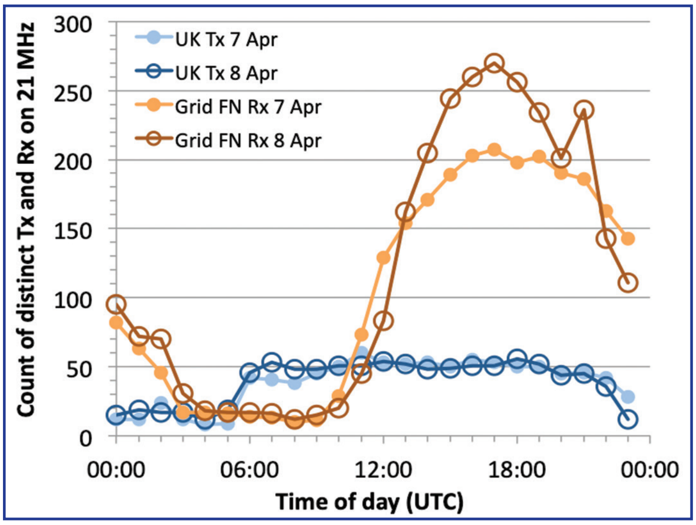

FIGURE 3: The number of active 21MHz WSPR UK transmitters and receivers in North America (Maidenhead grid-square FN) on eclipse day and the day before in one-hour intervals.

index Kp was 1.6, peaking at 3.3 [7].

Third, might the eclipse's effect on the transatlantic path be swamped by day-to-day variations in propagation? Comparing results for the eclipse day with those for the day before tackles that possibility.

Fourth, if one or more bands closed early, any effect from the eclipse would be lost. Encouraging use of 21MHz, 24MHz and 28MHz by UK amateurs sought to minimise the impact of early band closure [8].

Fifth, might changes in the number of transmitters and receivers active each day on each band obscure the eclipse's impact on propagation? The following WSPR-data analysis answers that question.

Figure 3 shows, by hour, the number of active 21MHz WSPR transmitters in the UK and receivers in North America (Maidenhead grid-square FN) on eclipse day and the day before. 'Active' means the transmitters were reported at least once, at any time within the hour, and that a receiver reported at least once. The graph shows that any dip at the second reflection eclipse time (1800 to 2100UTC) could not have been caused by there being fewer active UK transmitters. Clearly there were more WSPR receivers active in Maidenhead grid-square FN on the 8th than the 7th. A likely explanation for the dip at 2000UTC, from 235 either side to 201, was that, for a minority of receivers (34), the only 21MHz signals they were decoding were on paths affected by the eclipse. But the important conclusion is that any dip between 1800 and 2100UTC could not have been caused by a lack of active receivers.

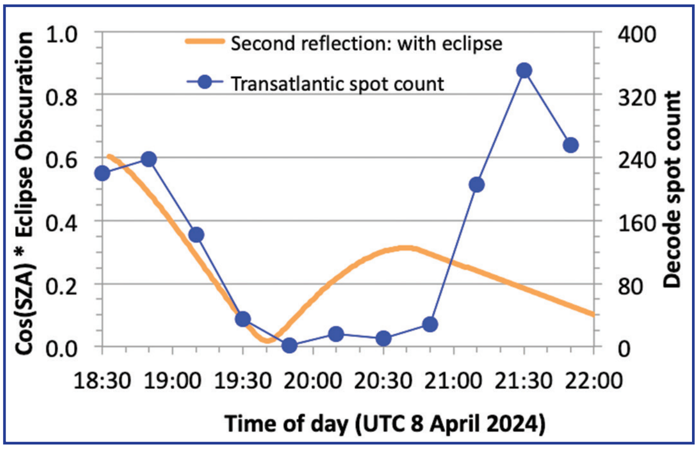

FIGURE 4: The solar input metric (orange) and the decode count for the transatlantic path on 21MHz (blue).

Results

The simplest analysis, a count with time of WSPR transmissions decoded, is sufficient to illustrate and give insight into the total eclipse's effect on higher HF-band transatlantic propagation. **Figure 4** repeats from Figure 2 the simple metric over the second reflection region, while adding the decode count in 20-minute intervals for 21MHz UK transmitters over headings 282° to 298° at ranges 4500km to 7000km received in North America. A choice of the count scale aligned the two metrics at 1800UTC.

As the eclipse progressed, the decode count reduced substantially. Only one transmission was decoded in the interval starting at 1940UTC (GW4SYI received at N5TNL, Arizona, at 6964km with signal-to-noise ratio -24dB in 2.5kHz bandwidth). While the fall-off in decodes followed the simple metric, the decode count remained low as the solar radiation increased again after the passage of the eclipse. A feasible explanation is that the eclipse caused the total electron count to drop, hence the F2-layer critical frequency reduced, resulting in the maximum useable frequency (MUF) for these two-hop transatlantic paths dropping well below 21MHz. It then took time for the MUF to rise again sufficiently for 21MHz decodes to recommence.

A more-detailed view of the eclipse's effect on higher-HF frequency transatlantic propagation emerges from decode count heat maps (see **Figure 5**). I apologise for the fonts being so small. In each panel, time of day is plotted from 1400UTC to 2200UTC horizontally, and the distance in units of 1000km from 4.6 to 7.0 vertically. Each pixel's colour represents the decode count within 20-minute and 200km intervals on headings 282° to 298°. The top row for 7 April provides a comparison with the eclipse day.

On 18MHz there was a clear reduction or absence, then a return of decodes out to 5600km caused by the eclipse. While numbers were small, decodes were first absent at shorter ranges, progressively reducing out to 5600km. The implication is that the MUF for two-hop paths of less than 5600km dropped below 18MHz. This is not shown, but the effect on 14MHz was small, there was no comparable gap in decodes to that seen at 18MHz and 21MHz. At 2000UTC on 8 April the 14MHz decode count over ranges between 4400km and 5600km was 424 compared with 523 on 7 April, a drop, but only of 19%.

On 21MHz loss of decodes also started at shorter ranges. Longer ranges saw decodes reduce (the deeper blues) bottoming out between 1940UTC and 2000UTC, with only the single decode at 6964km. Decodes returned initially at longer ranges as the MUF rose again. This was followed by a marked increase after 2100UTC between ranges 5400km and 5600km (New York and New England) to above the 7 April counts. A likely explanation is the higher number of active receivers in North America on eclipse day, Figure 3.

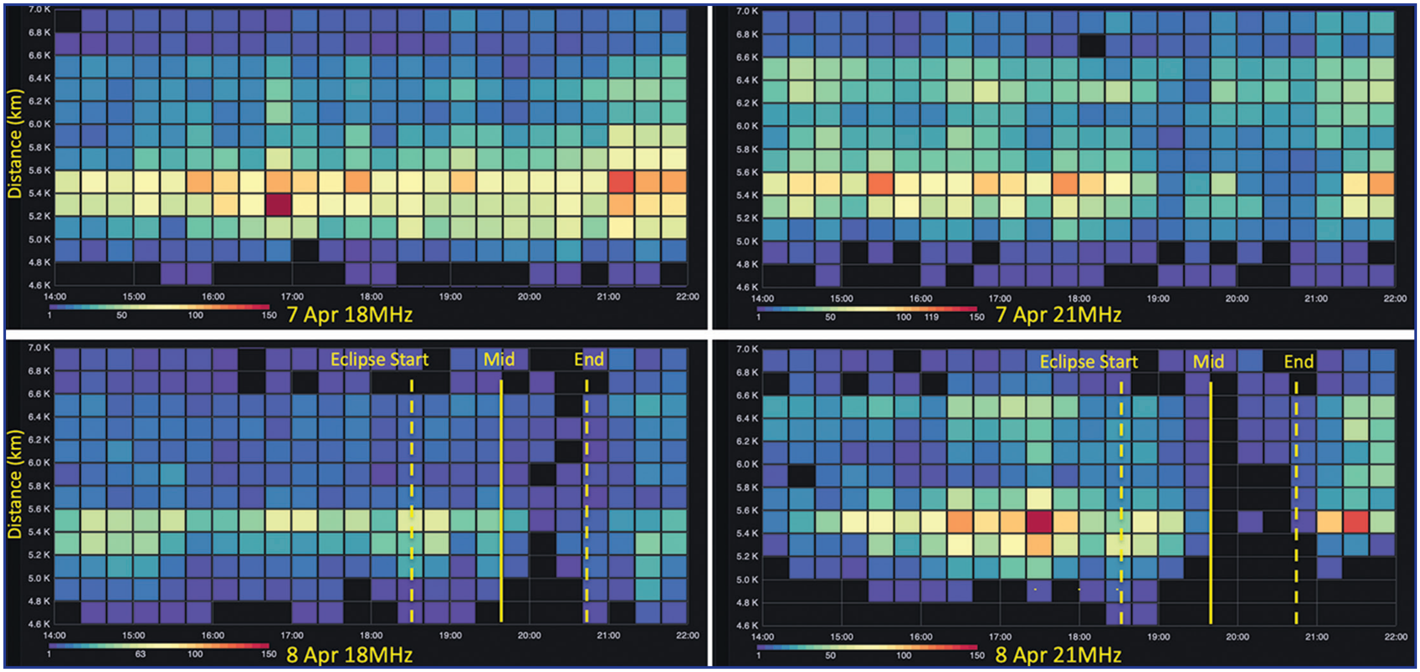

FIGURE 5: Heat maps with the pixel colour indicating the count of decodes within 20-minute and 200km intervals on 7 April (top row) and 8 April, eclipse day (bottom row). The left column is at 18MHz, the right at 21MHz. Eclipse start, mid, and end times at 49.8°N 59.6°W for the second reflection are also shown.

Conclusion

Despite not being visible from the UK the 8 April 2024 total eclipse had a substantial effect on the higher HF-band transatlantic propagation. On 21MHz no UK WSPR transmissions were decoded between 4600km and 6900 km in this study's transatlantic paths just after mid-eclipse over the region of the second reflection. Ray tracing was invaluable in both planning for the eclipse and in helping interpret the results. The absence of significant solar flares and geomagnetic disturbance made attribution of the observed dips to the eclipse straightforward.

Acknowledgements

PyLap uses the HF propagation toolbox, PHaRLAP, created by Dr. Manuel Cervera, Defence Science and Technology Group, Australia, available by request from manuel.cervera@dsto.defence.gov.au. I am grateful to Rob Robinett AI6VN for the WsprDaemon database and its tools, and to fellow WSPR enthusiasts for transmissions and submitting decodes. This work is a contribution to the HamSCI 'Festival of Eclipse Ionospheric Science'.

References

[1] https://hamsci.org/eclipse
[2] For example, an interactive map at http://xjubier.free.fr/en/site_pages/solar_eclipses/TSE_2024_GoogleMapFull.html
[3] https://svs.gsfc.nasa.gov/5073
[4] https://github.com/hamsci/pylap
[5] https://www.ukssdc.ac.uk/wdcc1/bulletins/if2igmb.lis (registration needed)
[6] Online calculator for solar zenith angle at https://gml.noaa.gov/grad/antuv/SolarCalc.jsp. The eclipse obscuration factor was calculated using AstroPy: A. M. Price-Whelan et al., 2018. The Astronomical Journal, 156(3): 123. Available via https://www.astropy.org/
[7] https://spaceweather.com/archive.php?view=1&day=08&month=04&year=2024
[8] News item. *RadCom*, 100(4): 14, April 2024