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Observation of the MF Broadcasting Wave Intensities on the Solar Eclipse

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Abstract

The ionospheric D region generated by sunlight has great influence on the MF wave propagation. To investigate the response on the D region during the solar eclipse, we observed the MF broadcast wave intensities for two similar periods, the annular and the partial solar eclipse in Japan. As a result, more MF broadcasts were observed during the partial solar eclipse although the partial solar eclipse had more sunlight than the annular solar eclipse.

1 Introduction

In night-time, we can receive the MF sky waves reflected from the ionospheric E or F layer. But in daytime, these waves cannot be received for strong attenuation in passing the D region generated by the ultraviolet and X-ray from the sun. On the solar eclipse case, the size of the D region changes along the local eclipse course. To investigate the response on the D region during the solar eclipse, we observed the MF wave intensities in two periods, the annular solar eclipse (May 21, 2012) [1] and the partial solar eclipse at Japan (Jan. 6, 2016). The two eclipses occurred at similar time from sunrise. In this paper, we report about the observation experiments and the observation results by comparing them.

2 Experiment

2.1 Receiving system

The receiving antenna was a vertical rod antenna for the annular eclipse and a dipole antenna for the partial eclipse. Therefore, the horizontal direction is omnidirectional. The receiving antenna was installed on the roof of the college building at Tsubata in Japan. Tsubata is located on the Sea of Japan in the nearly center of Honshu, Japan, and is suitable for observing ionospheric reflection waves of major MF broadcastings with a single frequency on the Pacific side in Japan. Figure 1 shows the observation system for the partial solar eclipse. It is the same observation system for the annular eclipse except for the antenna. In Fig. 1, the spectrum analyzer measured wave intensities every 1kHz with RBW 1 kHz and VBW 100 Hz on the MF broadcast frequency band between 500 kHz and 1500 kHz. The wave intensities were observed every 30 seconds.

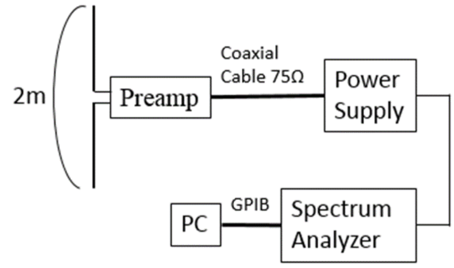

Figure 1. Observation system block diagram for partial solar eclipse.

2.2 Eclipses

The annular solar eclipse passed through Japan with 90% or more of sunlight blocked on May 21, 2012. And the partial solar eclipse passed through Japan with 20% to 40% shading of sunlight on Jan. 6, 2019. Figure 2 shows an estimate of solar power outside the atmosphere in Tsuruga using the solar constant of 1367 W/m^2. Tsuruga is the middle point when receiving the MF stations in Osaka. The maximum time of the solar eclipse was around 7:30 for the annular solar eclipse and around 10:00 for the partial solar eclipse. Although Fig. 2 shows that the characteristics of the sunlight from sunrise to the solar eclipse are similar. The annular solar eclipse has a much smaller solar power during the solar eclipse than the partial solar eclipse. The solar eclipse starts about 1 hour before the maximum and ends about 1.4 hours later.

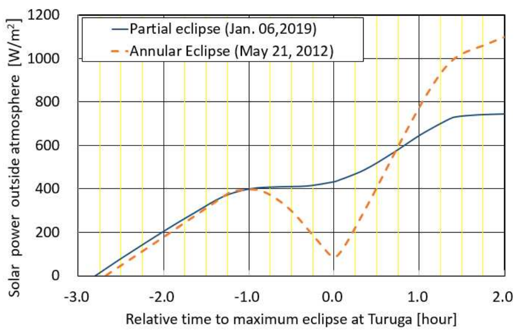

Figure 2. Solar power outside the atmosphere in Tsuruga using the solar constant of 1367 W/m^2 (The horizontal axis is the time based on the maximum shading time).

2.3 Observation of the MF broadcast wave intensities on the annual solar eclipse [1]

Figure 3 shows the field intensities at Tsubata from 3:00 to 9:00 [JST] on May 21, 2012. First, we generally explain the figure. The color bar shows the field intensity between 35 and 65 [dB(μV/m)]. The carrier frequencies of the MF radio broadcastings of Japan exist in every 9 kHz interval from 531 to 1602 kHz. The carrier transmission strength is constant, but the reception intensities fluctuate slightly due to the sideband of the voice signal. In the daytime, we receive only ground waves, for example, the waves of 648, 738, 909, 1107, 1224, 1386 kHz, etc. for neighborhood broadcastings. In the nighttime, all MF broadcastings of Japan are received with fading. Additively, the city noise band is strongly occurred near 560 kHz.

Next, In the annual solar eclipse, only a few waves such as 1179, 1242, 1314kHz have been stronger several dB than the city noise level, as circled in Fig. 3. But the other broadcasting waves have not remarkably changed. Both the 1179 and 1314 kHz waves are transmitted from Osaka which left about 260 km, and the 1242 kHz wave is transmitted from Kisarazu which left about 320 km. Focusing on the MF stations in Osaka, the effect of the solar eclipse appeared at 1179 and 1314 kHz. But, the effect of the solar eclipse did not appear at 666, 828kHz.

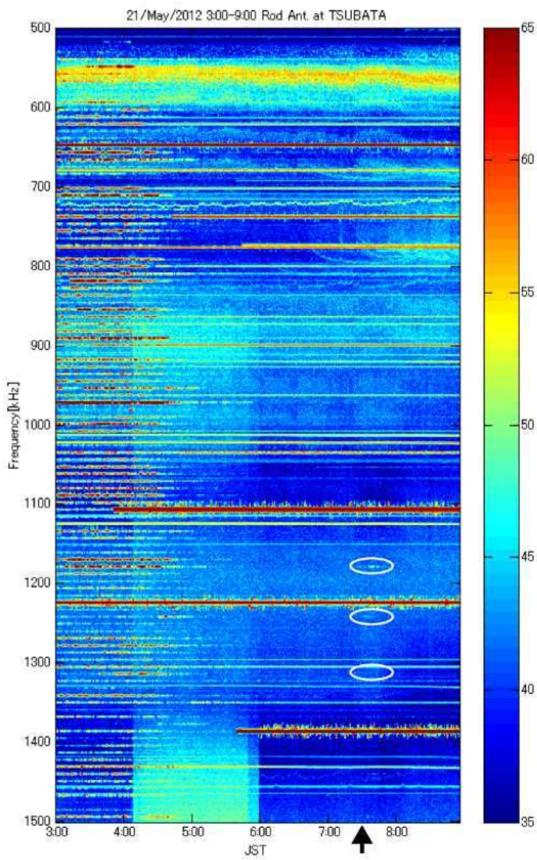

Figure 3. Field intensities on the annual solar eclipse (The black arrow indicates the maximum solar eclipse).

Figure 4 shows the field intensities for 1008, 1179 and 1314kHz in the MF Osaka stations. ionospheric reflection waves appear a little later than the maximum of the solar eclipse. For 1008kHz, a ground wave was measured in this observation, and interference with the ionospheric wave seems to be observed near the solar eclipse.

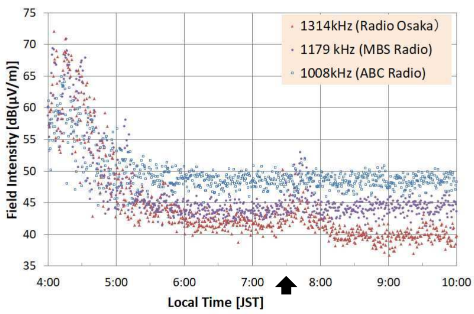

Figure 4. Field Intensities of 1008, 1179 and 1314kHz on the annual solar eclipse.

2.4 Observation on the partial solar eclipse

Figure 5 shows the field intensities at Tsubata from 6:00 to 12:00 [JST] on Jan. 06, 2019. Perhaps because the observation date was Sunday, the spatial noise is weaker than the annular solar eclipse, which is 35 dB or less. The vertical blue line indicates the time when data was lost.

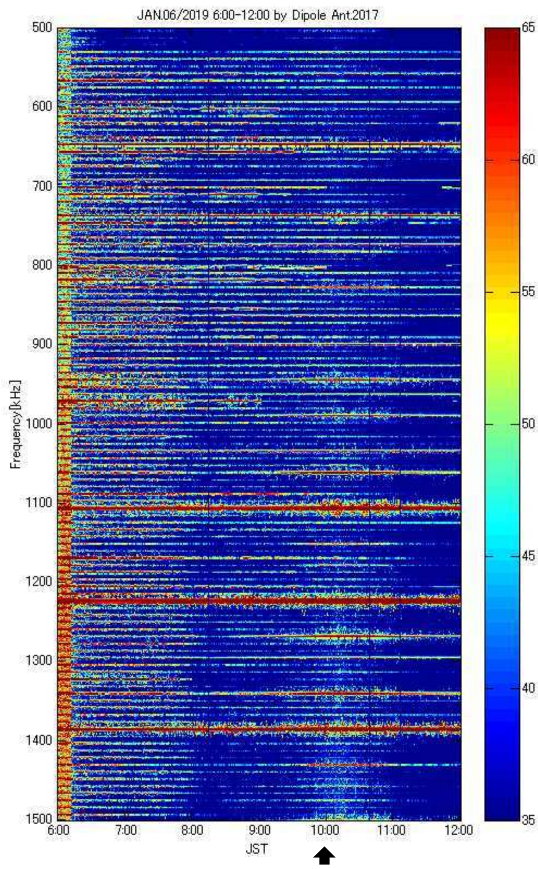

Figure 5. Field intensities on the partial solar eclipse (The black arrow indicates the maximum solar eclipse).

Next, In the partial solar eclipse, so many waves were observed, surprisingly. Figure 6 shows the field intensities for all MF waves in Osaka. The sunrise time is nearly 7:06 at Tsuruga. Fig. 6 shows that the radio waves are attenuated with solar radiation after the sunrise, but they start to increase near the start of the solar eclipse and are attenuated again as the solar eclipse ends. The 666 and 828 kHz waves, which did not appear in the annular solar eclipse, also appeared in this partial solar eclipse. For 1008kHz radio waves, the ground wave was not observed because the measurement location was slightly changed.

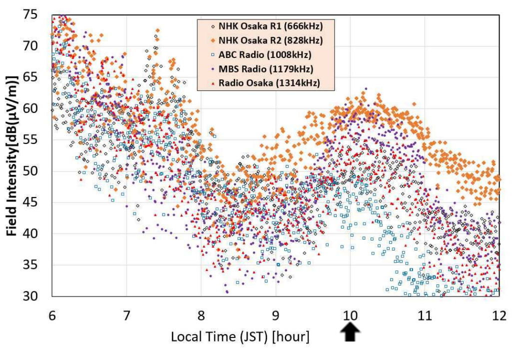

Figure 6. Field Intensities of 666, 828, 1008, 1179 and 1314kHz at Osaka on the partial solar eclipse.

3 Discussion

The difference between the partial solar eclipse and the annular solar eclipse will be considered from the sunspot number and the ionogram.

3.1 Sunspot number

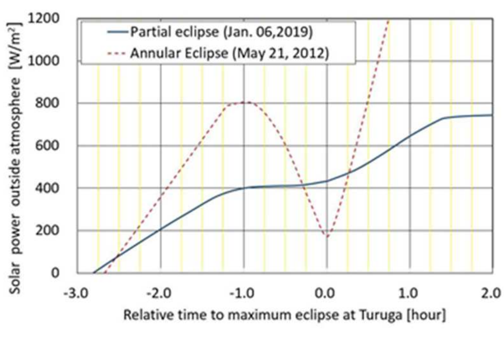

Figure 7. Solar power outside the atmosphere in Tsuruga using the solar constant of 1367(1+0.01R) W/m^2.

The sunspot number (R) on the annular solar eclipse was R=103, and R=0 on the partial solar eclipse [2]. The electron density profile in the ionospheric E and F layer correlates with the sunspot number. Assuming that there is a similar correlation in the D region, multiplying the solar power by (1 + 0.01R) gives Figure 7 from Fig.2. This assuming can explain that the field intensities decrease sharply with the sunrise as compared with the partial solar eclipse. And, since the lower MF frequency is more affected by the D region, it seems that 666 and 828 kHz could not be received during the annular solar eclipse.

3.2 HF field intensities from ionogram

From the ionogram observed at Kokubunji in Japan [3], we will investigate the ionospheric wave intensities from the higher MF to the lower HF region. Figure 8 shows the ionogram at maximum of the annual eclipse. And Figure 9 shows the ionogram at maximum of the partial eclipse. Receiving intensities is displayed in color. As shown in Fig. 9, the HF wave is generally less attenuated in the D region. However, Fig.8 of the annual eclipse shows that the HF waves are considerably attenuated. This may be because the ionosphere is not horizontal and does not have regular reflections. Therefore, during the annular solar eclipse, it may have been possible to receive only a few waves of the MF broadcastings.

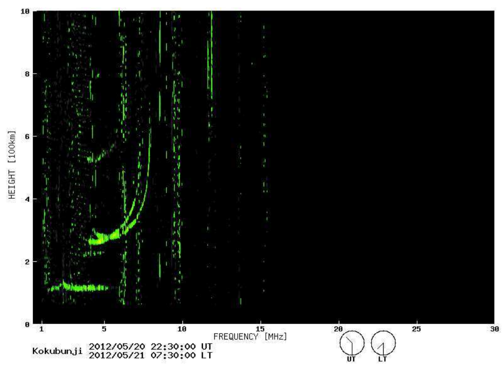

Figure 8. Ionogram at maximum of annual eclipse with filtered broadcast waves.

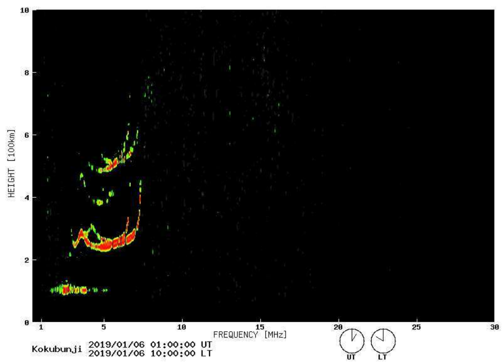

Figure 9. Ionogram at maximum of partial eclipse with filtered broadcast waves.

4 Conclusion

The ionospheric D region generated by sunlight has great influence on the MF wave propagation. To investigate the response on the D region during the solar eclipse, we observed the MF broadcast wave intensities for two similar periods, the annular and the partial solar eclipse in Japan. As a result, more MF broadcasts were observed during the partial solar eclipse although the partial solar eclipse had more sunlight than the annular solar eclipse. We tried to explain the reason using the sunspot number and ionograms.

5 References

1. T. Fukami, I. Nagano, and R. Higashi, "Observation of the MF Broadcasting wave Intensities during the Annular Solar Eclipse," *Institute of Image Information and Television Engineers*, **72**, 4, March 2018, pp. J73-J75 (in Japanese), https://doi.org/10.3169/itej.72.J73

2. Solar Science Observatory NAOJ, Mitaka, https://solarwww.mtk.nao.ac.jp/jp/db_sunspot.html

3. Ionospheric Sounding Data in JAPAN, https://wdc.nict.go.jp/ISDJ/ionospheric-signal.html