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The Impact of Partial Solar Eclipse on the Observation of Neutral Hydrogen Emission Line

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Abstract

The research involves examining the influence of partial solar eclipse on the strength of neutral hydrogen from the Sun. Baghdad University Radio Telescope (BURT) was used to monitor the partial solar eclipse on the 25th of October, 2022. Radio observations from the Sun were recorded from 11:30 AM to 03:36 PM. This means that the HI emission from the Sun was recorded before, during and after the event. It was noticed, that at the moment of maximum eclipse, ~ 46% of the Sun's disk was covered by the Moon. For the purpose of this research, the solar radio wave intensity was monitored and the solar flux density was determined at different times, i.e. before, during and after the partial solar eclipse. The obtained results showed that both of the solar flux and power spectrum decrease with the progress of the eclipse until the moment of maximum eclipse, i.e. the moment at which the minimum values of solar flux density and antenna temperature were recorded (7×10^4 Jy and ~ 80 K). Then, at the last moments of the partial eclipse, it was noticed that both parameters started to increase again due to the decrease in the area of the Sun's disk until both reached their normal values. In Conclusion, the partial solar eclipse affects the strength of neutral hydrogen from the Sun because the Moon blocks the neutral hydrogen from the Sun during the solar eclipse.

Keywords: Solar eclipse, radio sun observation, antenna temperature, flux density.

تأثير كسوف الشمس الجزئي على رصد خط انبعاث الهيدروجين المتعادل

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الخلاصة

يتضمن هذا البحث اختبار تأثير الكسوف الجزئي للشمس على شدة الهيدروجين المتعادل من الشمس.حيث تم في العام الماضي رصد الكسوف الجزئي للشمس الذي حدث في 25 تشرين الأول/أكتوبر باستخدام تلسكوب جامعة بغداد الراديوي (BURT). وتمت عملية الرصد من الساعة 11:30 صباحًا حتى 3:36 مساءً، وذلك لتسجيل الإشارة الراديوية من الشمس قبل وأثناء وبعد الكسوف الجزئي للشمس. وفي لحظة الكسوف القصوى، كان القمر يغطي 46% من قرص الشمس. ولتحقيق الهدف من هذا العمل، تم رصد وتسجيل شدة الموجات الراديوية القادمة من الشمس وحساب كثافة التدفق الشمسي في أوقات مختلفة قبل وأثناء وبعد الحدث. وأظهرت نتائج هذا العمل أن طيف الطاقة وكذلك الفيض الشمسي يتناقصان مع تقدم الكسوف الجزئي للشمس حتى حدوث الكسوف الأقصى. في تلك اللحظة، تم تسجيل القيم الدنيا لدرجة حرارة الهوائي

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وكثافة الفيض الشمسي ووجد أنها ~ 80 K و7×10^4 Jy، على التوالي. وبعد ذلك، بدأت مساحة قرص الشمس التي يغطيها القمر بالتناقص مرة أخرى، وبالتالي بدأ الفيض الشمسي في الزيادة مرة أخرى. وهذا يدل على ان كسوف الشمس الجزئي يؤثر على قوة الهيدروجين المتعادل من الشمس. ويرجع ذلك إلى حقيقة أن الهيدروجين المتعادل من الشمس قد حجبه القمر أثناء كسوف الشمس.

1 Introduction

A partial solar eclipse is an astronomical natural phenomenon, where a solar eclipse's maximum period is approximately two to three hours. In a partial eclipse, the moon's shadow moves at the supersonic speed of about 500 to 1000 m/s, and this shadow travels depending on the geographic latitude [1]. A solar eclipse acts significantly to produce a variation in different fields, such as the atmosphere, ionosphere, and magnetosphere. The previous fields are changed quantitatively and qualitatively in different processes due to solar eclipsing. Therefore, the solar energy flux largely decreases during an eclipse, while a little changing at the zenith angle only about (8 % to 12 %). In general, the solar eclipse is a unique event and beneficial for astronomers to study the occurring physical and chemical processes in the atmosphere. This is particularly because a solar eclipse event depends on several factors such as local time, season, and space weather [2]. Solar eclipses have been studied by astronomers a long time ago, for instance, early in the twentieth century; the upper atmosphere and ionosphere were investigated. The effects arising throughout solar eclipses were first monitored and published as early as 1930–1940s, (e.g., Chapman, 1932; Higgs, 1942) [3, 4]. Then, several studies tackled solar eclipsing, but the first radio solar physics was published in 1944. In this study, high spectral and time resolution radio observations of solar eclipse were carried out at Chapeco, Brazil for the first time [5]. After that, solar radio physics was born. Following this development, several interesting books with details for introducing solar radio physics keep momentum in the field [6]. The properties of radio waves distorted due to the solar eclipse were first recorded and published in 1950s (Beynon and Brown, 1956) [7]. For solar radio astronomy studies, total or partial eclipses provide great opportunities for solar radio observations, which are primarily time-dependent. Furthermore, several radio solar eclipse observations were carried out in China in 1958, 1968, 1980 and 1987, the findings were briefly introduced [5, 8].

The research aims to analyze the solar radio intensity at a frequency of 1.42 GHz before, during and after the partial solar eclipse on October 25, 2022. These analyses have been performed using observational data of the sun using the Baghdad University Radio Telescope (BURT). This telescope is being used by astronomers at the University of Baghdad to examine several aspects of radio astronomy. Astronomical observations from small radio telescopes like BURT are usually used to investigate various astronomical sources and phenomena; one of which is measuring the Galactic rotation curve, for example [9, 10]. However, the focus in research was on monitoring the potential difference in the antenna power, antenna temperature, and solar flux density due to the impact of a partial solar eclipse.

2 Observations

A partial solar eclipse happened on October 25, 2022 (maximum of eclipsed area 46%). It was observable from Baghdad and hence the idea was to observe the impact of this event on the intensity of radio signal from the Sun. The radio observations of the eclipse were made using BURT, (Longitude: 44^{o} 22′ 48″, Latitude: 33^{o} 16′ 30″). This telescope has a diameter of 3 meters; BURT is centered at 1.42 GHz with a half-power beamwidth (HPBW) of 4 degrees [11].

The raw power data were recorded by selecting the optimum values of BURT's spectrometer parameters. These parameters include span (2 MHz), sweep time (30 sec), Resolution Bandwidth (RBW = 1000 Hz), and Video Bandwidth (VBW =10 Hz).

It should be mentioned that the future steps involve observing further solar eclipses using BURT to investigate its influence on radio observations. In addition, this research is a part of the project that aims to discuss the applications of BURT so that further observations will be carried out using BURT to investigate various astronomical problems.

3 Results and Discussion

The first two observations at 11:30 AM and 11:55 AM before the partial solar eclipse occurred have been recorded, as shown in Figure 1.

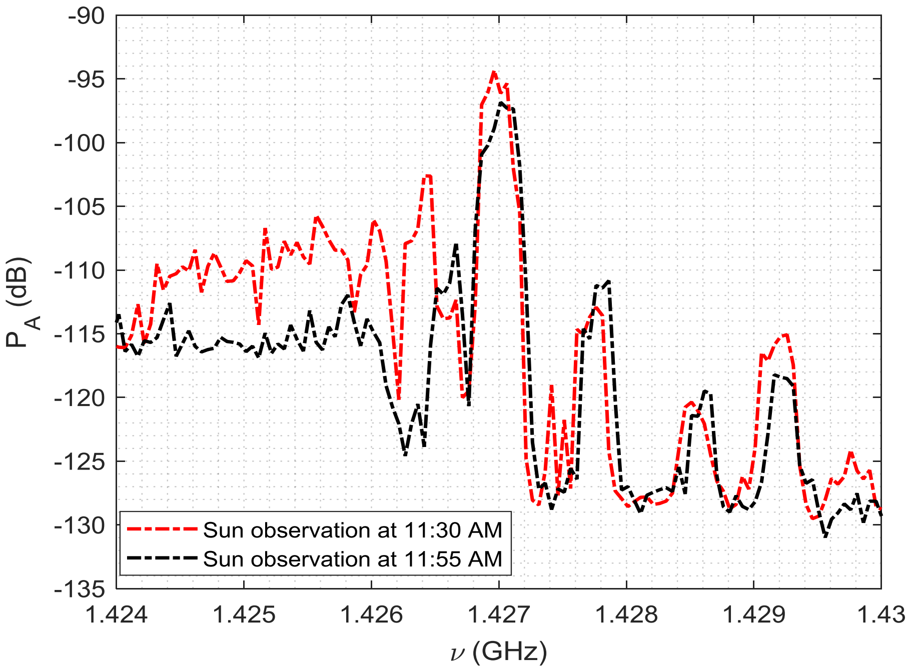

Figure 1: Recording antenna power (P_A) as a function of frequency (v), before eclipsing. (Date Oct. 25, 2022). Note (dashed red line at 11:30 AM, and dashed black line at 11:55 AM).

The other two observations were recorded during the partial solar eclipse, particularly at 1:20 PM and 2:06 PM. The antenna powers of these two observations are shown in Figure 2. This figure clearly illustrates that the emission intensity decreases with time during the progress of the partial solar eclipse. This is due to the increase of the covered area of the Sun by the moon during the partial solar eclipse.

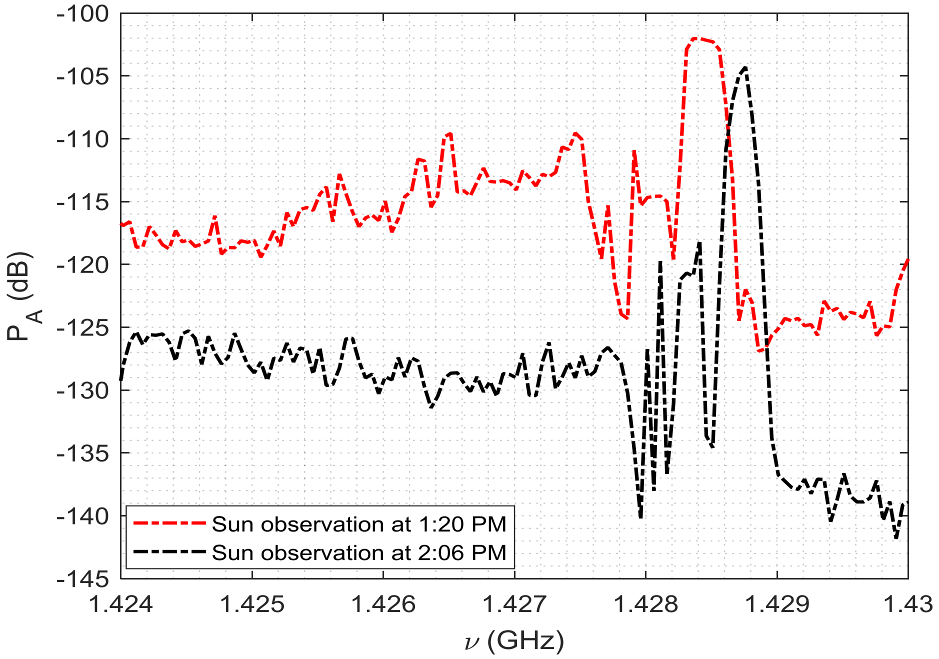

Figure 2: Recording antenna power (P_A)as a function of frequency (v), during the eclipse.

After, an observation was recorded at 2:24 PM, which was the time when the maximum partial solar eclipse occurred and hence the covered area was the largest at that moment. Therefore, the antenna power in that case represented the minimum received signal from the Sun during the event, as shown in Figure 3.

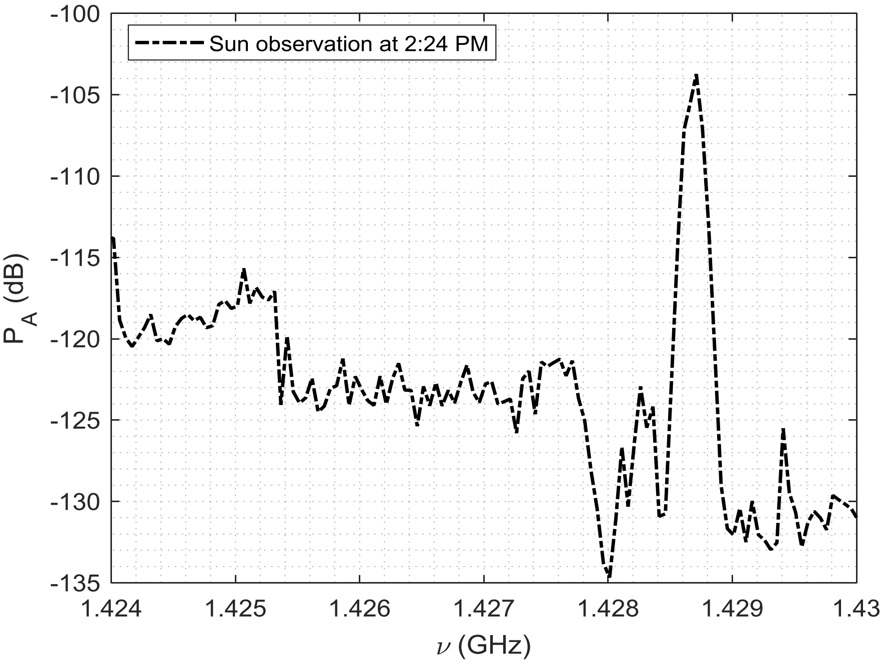

Figure 3: Recording antenna power (P_A)as a function of frequency (v), at the maximum of eclipsing.

Finally, two observations were carried out at 3:25 PM and 3:36 PM as shown in Figure 4. This figure demonstrates that the signal increases again after the partial solar eclipse ends.

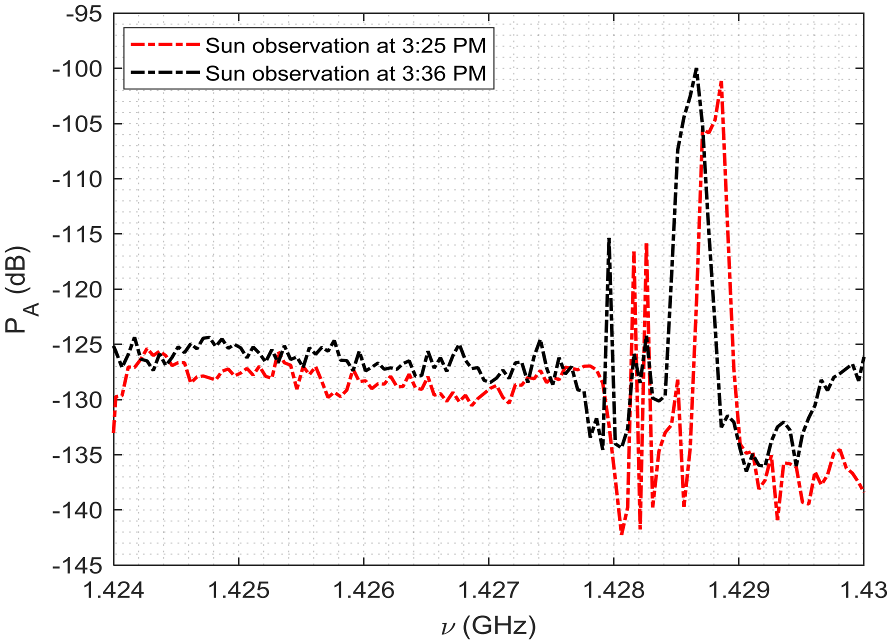

Figure 4: Recording antenna power (P_A) as a function of frequency (v), after the eclipse.

The antenna temperature (T_A) is usually defined as the temperature of the radio source as sensed by a radio telescope antenna. The T_A can be expressed using the Nyquist theorem as follows [12]:

$$T_A = \frac{P_A}{kG\Delta v} \tag{1}$$

Where: P_A is the antenna power or the received power, k is Boltzmann constant, G is the telescope gain and Δv is the bandwidth frequency in Hz, which is given by [13]:

$$\Delta v = N_{ch}\Delta v_{ch} \tag{2}$$

Where: N_{ch} is the number of spectrometer channels and Δv_{ch} is the frequency width of the channel.

In the radio observation, T_A can be given by [14]:

$$T_A = T_{A-on} - T_{A-off} \tag{3}$$

Equation (3) represents the subtraction between T_{A-on}due to the observed source and T_{A-off} due to the sky noise. In this problem, the noise is generated using the noise calibration unit device. This device consists of a noise diode that generates a calibrating signal to inject the telescope receiver and is equivalent to the sky noise associated with the observed signal. The injected noise in the system is dominated at a frequency of 1.42 GHz. Therefore, T_{A-off} can be given by [15]:

$$T_{A-off} = \frac{p_{off}}{Gk\Delta v} \tag{4}$$

Where: p_{off} is the noise power generated using the noise calibration unit.

Figure 5 shows the antenna temperature measured using Equation 3 for observing the Sun before, during and after the partial solar eclipse. This figure clarifies that the maximum antenna temperature occurs before the solar eclipse, whilst it decreases during the eclipse until it reaches the minimum value at the moment of the maximum eclipse.

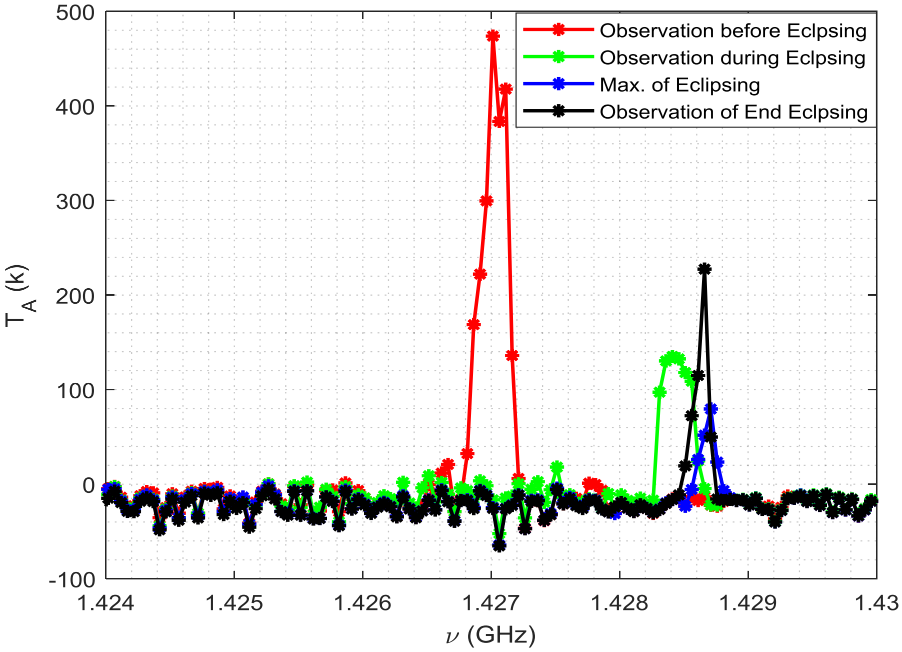

Figure 5: Measured antenna temperature (T_A) due to the Sun observations as a function of frequency (ν).

The observed solar radio flux density (S_o) is often expressed in terms of T_A as [16]:

$$S_o = \frac{2kT_A}{A_e} \tag{5}$$

Where: A_e is the effective area. A_e of the BURT is equal to 3.5 m^2 [11].

The real observed solar flux density (S) is obtained from the difference between the observed solar flux density and that due to the contribution of the radio noise as follows [17]:

$$S = S_o - S_n \tag{6}$$

Where: S_n is the flux density of the noise calibration unit. S_n is equivalent to the flux of a sky background noise.

A cubic function fit to the results of solar flux density has been performed using Matlab and the fitted curve along with the fitting equation is shown in Figure 6. The figure demonstrates that the solar flux density decreases with time during the partial solar eclipse until it reaches its smallest value at the point of maximum solar eclipse. Then, it starts to increase again after the end of the event. Eventually, the results of this research agree with those of a recently published article [18].

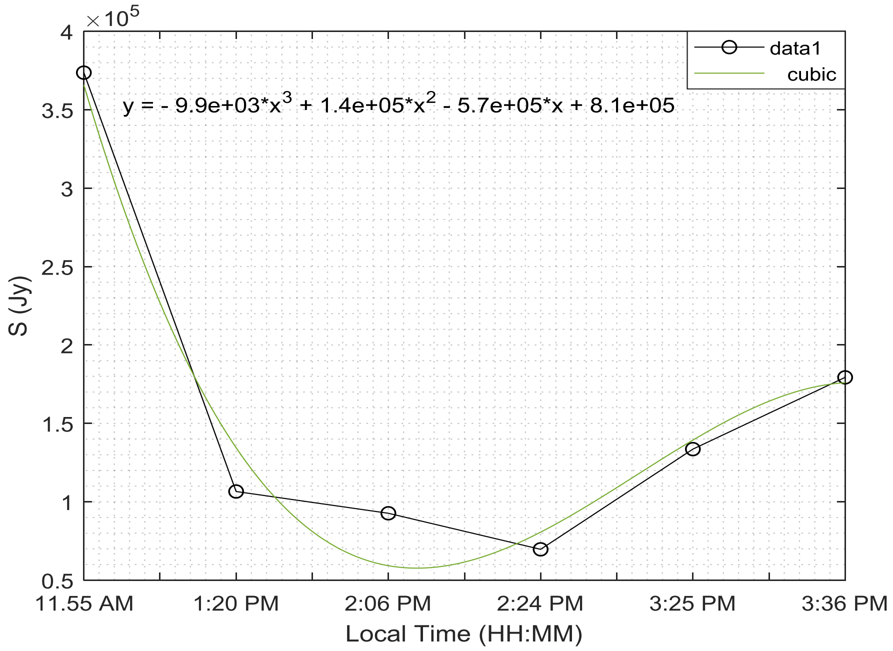

Figure 6: The measured solar flux density (S) as a function of the local time.

To further investigate the impact of partial solar eclipse on the emission of neutral hydrogen from the sun, the percentage decrease of the antenna temperature at the wavelength of 21 cm has been determined using the following formula:

$$PD = \left|\frac{T_{A-after} - T_{A-before}}{T_{A-before}}\right| \times 100\% \tag{7}$$

Where: $T_{A\text{-}before}$ and $T_{A\text{-}after}$ are the solar antenna temperature of the 21-cm line before and after the partial eclipse. The results of the percentage decrease are shown in Figure 7. The figure clearly shows that the antenna temperature decreases enormously due to the effect of solar eclipse with the maximum percentage decrease of 83.1 % at 02:24 PM (i.e. at the time of maximum eclipse).

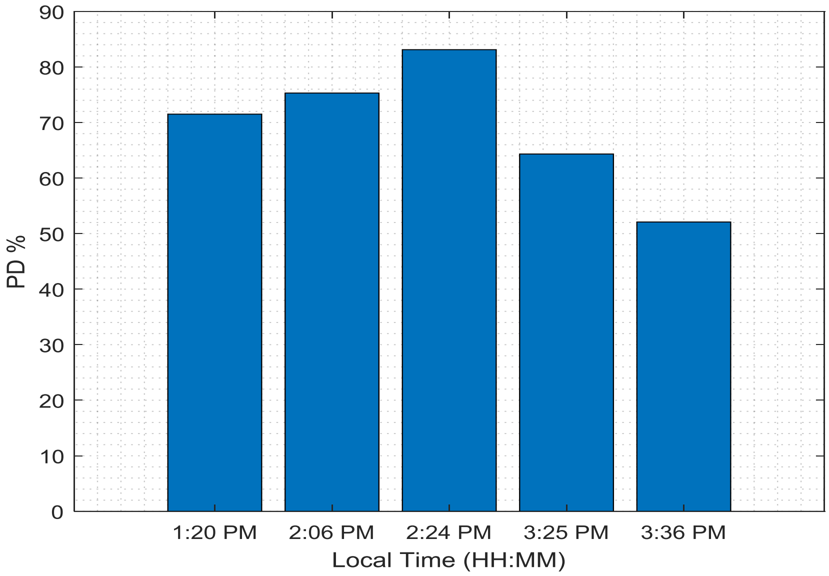

Figure 7: The solar antenna temperature percentage decrease (PD) as a function of the local time.

4 Conclusions

Several important points could be drawn from the results of this study as listed below:

1. The partial solar eclipse impacts the intensity of received signal of neutral hydrogen from the Sun due to the covered area of the Sun's surface by the Moon during the solar eclipse.
2. The antenna power of the Sun observations decreases with time during the partial solar eclipse. Whereas it starts to increase again after the end of the event.
3. The partial solar eclipse affects the antenna temperature. It was found that the maximum value of T_A gradually decreases with time during the progress of eclipsing. This value was estimated and found to be 473 K before the eclipsing, while it was recorded to be about 80 K at the maximum eclipsing.
4. The eclipsing leads to a little shift in the observed central frequency due to the gravity of the Moon. The maximum peak is located at 1.427 GHz before the eclipsing and then is shifted to near 1.429 GHz at maximum eclipsing. The signal peak shifted backwards to the observed frequency at the end of the eclipsing, as shown in Figure 5.
5. The solar flux density is affected by the partial solar eclipse. The minimum value of the observed solar flux density S was measured at the moment of maximum eclipsing and found to be equal to 70000 Jy. While the solar flux density values before and after the event were higher than 70000 Jy.
6. The relationship between the solar flux density and local time during the event is found to be governed by the cubic mathematical function.
7. The measurements of the solar antenna temperature percentage decrease showed that the partial solar eclipse influences the emission of the 21-cm line and the maximum percentage decrease at a maximum eclipse.
8. Finally, it should be mentioned that a similar behavior was discussed by a previously published article [18], and hence the results of this research agree with those of previous works. In addition, further observations of the Sun using BURT will be conducted to investigate the 21-cm emission line from the Sun.

Acknowledgement

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Conflict of Interest

The authors declare that they have no conflicts of interest**.**

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