

Ionospheric Absorption Effects of the Solar Eclipse of 24 October 1995

Wen Zeng¹, Xunjie Zhang¹ and Zerong Huang¹

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ABSTRACT

The solar eclipse of 24 October 1995 was observed in Wuhan. Field strength equipment was used to detect the radio wave absorption in the D-region and absorption data on the eclipse and control days were obtained. The comparison of these curves shows that the absorption values during the eclipse are less than the normal values. It was found that absorption effects began before the first contact and ended after the last contact.

(Key Words: Absorption effects, D-region, Solar eclipse)

1. INTRODUCTION

High frequency radio waves propagate by reflecting in the ionosphere. Their reflecting points are generally in the E and the F-region, but their energy loss mainly takes place in the ionospheric D-region. That is to say, the D-region's electron density is responsible for the absorption of HF radio waves. Sometimes we use the absorption measurement methods to observe the ionospheric variation including the electron density, collision frequency, long-periodic fluctuation in the mesosphere and so on.

During a solar eclipse, the variation of radio absorption comprises of two parts when reflection takes place in the E-region, namely, the nondeviative absorption and the deviative absorption (Zhang *et al.*, 1985). In general the critical frequency in the E-region decreases, the height of the reflection increases and the deviative absorption may increase. Moreover, because of the ionospheric tilt produced by the solar eclipse, radio wave energy undergoes focusing and defocusing; it also influences the measurement of absorption.

Much research has been done on the D-region ionosphere. The sources of ionization in the D-region are: (1) Ionization of the atmospheric constituents by cosmic rays. This is the predominant source of ionization in the polar region. The contribution of cosmic rays to D-region ionization decreases with latitude, becoming negligible at low latitudes; (2) Ionization of mesospheric nitric oxide by hydrogen Lyman- α emission from the sun; (3) Ionization of

¹Wuhan Institute of Physics and Mathematics, The Chinese Academy of Sciences, Wuhan, Hubei, 430071

molecular oxygen and nitrogen by solar X-rays of wavelengths less than 100 \AA ; (4) Ionization of O_2 (Δg) by $1027 < \lambda < 1118 \text{ \AA}$ UV radiation. The dominant source in a nonpolar latitude changes from cosmic rays to Lyman- α to X-rays as one moves from the lower to the higher mesosphere, so X-rays are responsible for the variation in electron density below the reflecting height in the altitude range where most of the absorption takes place (Sengupta, 1980). But J. Laštovička *et al.* (Laštovička *et al.*, 1982) consider solar Lyman- α to play the dominant role in the D-region radio wave absorption. We could conclude that the source of the D-region is the sun and the electron density in the D-region is mainly controlled by the sun. When the sun's activity is strong, *e.g.* under flare condition, X-rays or Lyman- α flux increase and the electron density becomes higher, so the absorption of short radio waves increases. During the solar eclipse, the moon obstructs a part of the sun's radiation. The source of the D-region ionosphere partially fades away, so the electron density decreases. The absorption of radio waves correspondingly weakens. The results of our experiments are consistent with those above. In this paper, the observation experiment performed during the solar eclipse is introduced and the results of our experiment are given.

2. OBSERVATION

A solar eclipse may be viewed as a vast geophysical experiment where the rapid but predictable change in solar ionizing radiation presents a unique opportunity to study the changes that occur within the middle and upper atmosphere. Such an opportunity was anticipated for 24 October 1995 in southern China.

During the solar eclipse, we did our observation experiments in the Wuhan Institute of Physics and Mathematics ($30^\circ 38' \text{N}$, $114^\circ 17' \text{E}$). We used Field Strength Equipment to detect the absorption of HF radio waves. This is the so-called A3 method (Schwentek, H., 1966). This method has the advantage of being both simple and sensitive. Though the calibration is somewhat difficult, we are usually interested in changes in absorption, so accurate knowledge of the zero absorption level is not critical.

The main parameters of our instrument are listed as follows:

Frequency Bands: 150 KHz — 30 MHz

Frequency Errors: $< \pm 2\% \pm 2 \text{ KHz}$

Field Strength Range: 28 — 118 dB

Surveying Errors: $< \pm 3 \text{ dB}$

In Wuhan we received the short radio wave signals transmitted from Taipei ($25^\circ 02' \text{N}$, $121^\circ 31' \text{E}$). Since the distance between Wuhan and Taipei is about 950 kilometer, the circuit should be a one-hop path. The reflecting point's latitude and longitude are $27^\circ 50' \text{N}$ and $117^\circ 54' \text{E}$, respectively, and is located in the northeast of Jiangxi province. This arrangement moves the reflecting point near to the zone of solar eclipse. There the totality is about 0.50. The frequency of the radio waves is 9.6 MHz.

An absorption in the ionosphere is usually divided into nondeviative and deviative absorption. The absorption coefficient in the ionosphere can be expressed as (Davies K., 1989)

$$\beta = \frac{e^2}{2\epsilon_0 mc\mu} \frac{N\nu}{\omega^2 + \nu^2} \quad (1)$$

In nondeviative absorption regions, $\mu \approx 1$, and for HF radio waves, $\omega^2 \gg \nu^2$, so (1) can be simplified

$$\beta \approx 1.15 \times 10^{-6} \frac{N\nu}{f^2} \quad (2)$$

This is the type of absorption to HF and VHF waves that occurs in the D-region, where β is in decibels per meter. In deviative absorption regions, μ is close to zero, and the absorption coefficient is written approximately as

$$\beta \approx \frac{\nu}{2c} \mu' \quad (3)$$

where μ' is the group refractive index and β is in decibels per meter.

3. RESULTS AND DISCUSSIONS

The received energy can be divided into three parts: 1. the transmitted power; 2. the path attenuation; 3. the ionospheric absorption. Since we know the transmitted power and can calculate the attenuation along the path, we can draw the absorption curves according to the received field strength.

In our experiment, we also used LF radio receivers to receive Loran-C signals transmitted from Niiijima, Japan(34°24'N, 139°16'E). We studied the phase and amplitude of LF(100KHz) and the ionospheric critical frequency around the day of the eclipse, and found that none of these changed significantly. So we can conclude that the model of propagation didn't vary significantly during the solar eclipse.

Figure 1 shows the absorption data for the eclipse day (24 October) and adjacent days. The absorption curves of normal days have almost the same appearance: values increase in the morning with maxima appearing around noon, and then in the afternoon, values decrease. This corresponds to the variation of solar radiation flux in the local D-region. From Figure 1, we can see that the absorption values on 24 October 1995 didn't increase in the morning.

In Figure 2, the absorption values for the eclipse day are contrasted with the mean values for the control days. The ionospheric absorption effects during the eclipse are easily seen. The absorption values clearly didn't increase as they did on the control days. The longer bars on the X-axis indicate the start and end times of the solar eclipse's absorption effects. They are at about 10^h20^m (120°E, LMT) and 13^h55^m (120°E, LMT), respectively. In Wuhan the time of first contact was 10^h53^m (120°E, LMT), the middle of the contact period was 12^h10^m(120°E, LMT), and the last contact was 13^h28^m(120°E, LMT). From Figure 2, we can see that the absorption effects are evident both before the first contact and after the last contact. The time gaps are about 30 minutes.

In general terms solar irradiance originates near the photosphere at 3000 Å and approxi-

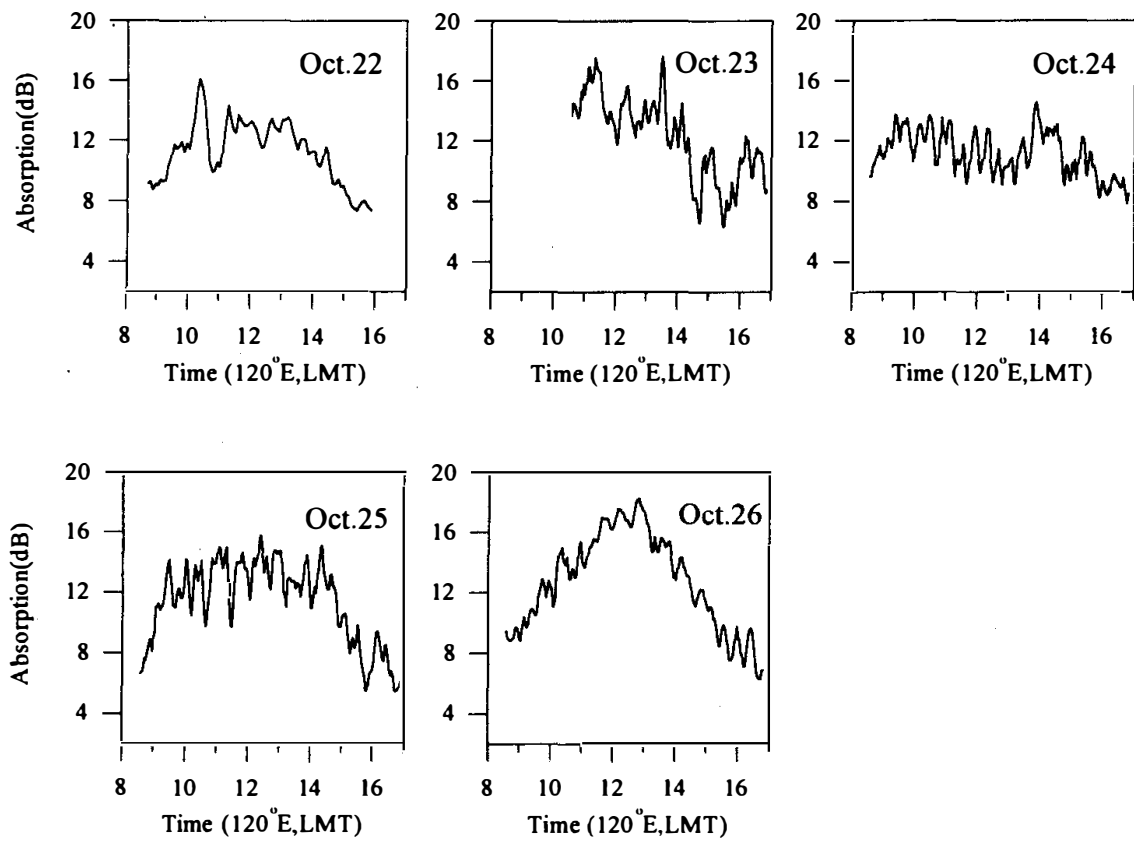


Fig. 1 Absorption recorders for the eclipse and control days.

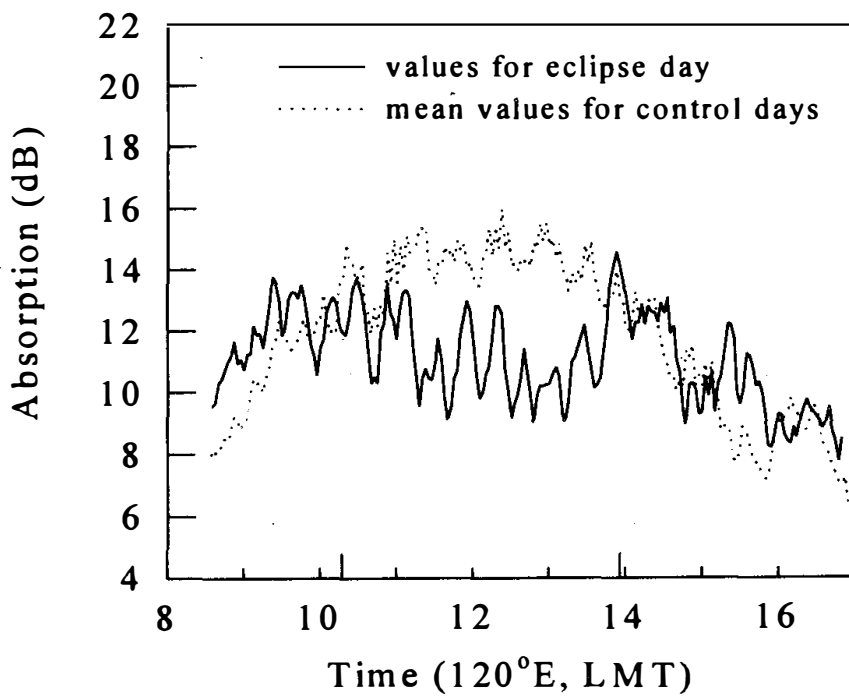


Fig. 2 Contrast of the solar eclipse and normal values.

mates a continuum down to 1500 \AA with superposed emission and absorption lines. Moving toward shorter wavelengths, the emission arises from higher layers of the solar atmosphere (Rottman, 1987). During a given period, each EUV flux is keyed to a chromospheric (e.g. Lyman- α) or coronal (e.g. $50 \text{ \AA} < \lambda < 100 \text{ \AA}$) emission (Tobiska, 1990). We know that the chromosphere is partially, and the corona completely, invisible. So, a radiation eclipse may last longer than an optical eclipse, beginning before first contact and ending after last contact. Perhaps this is one of the reasons for the above phenomena.

We also used a fractal technique (Essex, 1991) to calculate correlation dimensions for the data in our experiment. The fractal dimensions of the data for 24, 25 and 26 October are 2.231, 2.212, and 2.236, respectively. No obvious difference exists among their correlation dimensions. We consider the reason is that the totality of the reflecting points is only about 0.50. The influence of the solar eclipse is too weak to make a difference to the correlation dimension.

REFERENCES

- Davies, K., 1989: Chap. 7, Amplitude and phase, Ionospheric Radio. Peter Peregrinus Ltd., 214pp.
- Essex, C., 1991: Correlation dimension and data sample size. In: D. Schertzer and S. Lovejoy (Eds.), *Scaling, Fractals and Non-linear Variability in Geophysics*. Kluwer Academic Publisher, 93pp.
- Laštovička, J. and J. Boška, 1982: The dominant role of solar Lyman- α in D-region radio wave absorption. *J. Atmos. Terr. Phys.*, **44**, 793-795.
- Rottman, G. J., 1987: Results from space measurements of solar UV and EUV flux. In: P. Foukal (Eds.), *Solar Radiative Output Variation*. Cambridge Research and Instrumentation, Inc., 71pp.
- Sengupta, P. R., 1980: Solar X-ray control of the D-region of the ionosphere. *J. Atmos. Terr. Phys.*, **42**, 339-355.
- Tobiska, W.K., 1990: A solar extreme ultraviolet flux model. Univ. of Calif., Berkeley, 2-1pp.
- Zhang, X. J. and Xiong Nianlu, 1985: HF scattering by field-aligned irregularities in the equatorial E-region during total solar eclipse. *J. Atmos. Terr. Phys.*, **47**, 945-949.

