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Observations on the Occultation of the Radio Source Tauras A by the Solar Corona during June 1971

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Observations on the occultation of the radio source Tauras A (3C 144) during June 1971 at a wavelength of 12 m are presented. It is tentatively observed that there is no strong dependence between the amount of scattering and solar activity.

1. Introduction

IT WAS FIRST pointed out by Machin and Smith[1] that information about the outer solar corona can be obtained by observing the occultation of the radio sources by the solar corona. As radio waves pass through the corona, they get scattered, due to the fact that the electron density (and consequently the refractive index) varies from point to point. The effect of scattering is manifested by an apparent increase in the angular diameter of the radio source. It is suggested that the amount of scattering at a particular distance from the sun is approximately proportional to the average electron density at that point. It is now well established that the amount of scattering varies as the square of the observing wavelength. Thus, by observing at long wavelengths one can explore the outer most regions of the solar corona. Observations at various wavelengths and at different epochs of solar cycle are necessary for a complete understanding of the scattering phenomenon and also the structure of the outer corona. The radio source Tauras A (3C 144) which lies close to the plane of the ecliptic passes as near as about 5 solar radii and so will be occulted by the solar corona around the period June 14 to 15 every year. We have tried to observe the occultations during the years 1969, 1970 and 1971. Due to the interference of the radio emission from the disturbed sun our observations were not complete during the years 1969 and 1970. A fortuitous lull in solar activity during June 1971 enabled us to obtain useful results and these are reported here.

2. Equipment

These observations are made with a two-element phase switched (multiplying) interferometer at a wavelength of 12 m. The antenna system consists of two dipole arrays, one with 72 and the other with 32 full wave dipoles. The effective beam width of the antenna system is of the order of 7° in Right Ascension and about 14° in declination. The beam can be pointed anywhere within ± 30° of the zenith by manual phasing. The two elements of the antenna system are spaced about 360 meters apart which gives a fringe spacing of the order of 2°. We have previously used this antenna for high temporal resolution observations of the radio bursts from the sun[2-5].

The receiving system is of the Ryle phase switching type and its block diagram is given in Fig. 1, which is self-explanatory. The system noise temperature is of the order of 600°K and the predetection bandwidth is 13 kHz. The post-detection time constants ranged from 0·5 to 10 sec. At the wavelength of 12 m the sky noise completely dominates the receiver. It is found possible to obtain a signal-to-noise ratio of better than 5 on radio sources with flux densities of the order of 500×10^{-26} W/m^2/Hz.

3. Observations

During June 1971 we observed the radio sources Tau. A (3C 144) and 3C 123 at the time of their transit each day. We have obtained data on both the radio sources on 12 days. On three days we have observations only on 3C 144. During the rest of the days the data are not useful because of terrestrial interference and/or contamination due to the radio bursts from the sun. In Fig. 2 we have reproduced the records obtained on June 9, 10, 11, 17, 29, 1971. The reading accuracy of individual records is better than 5% and the scatter of day-to-day-values is about 10 to 15%.

Fig. 3 (a) shows the calibrated fringe amplitudes of the radio source 3C 123 and it is obvious that they are very nearly constant. Fig. 3 (b) shows the ratio of the fringe amplitudes (3C 144/3C 123) normalized to the preoccultation value. It can be seen that the normalized fringe amplitude dropped to about 0·3 when the angular distance of the radio source from the sun

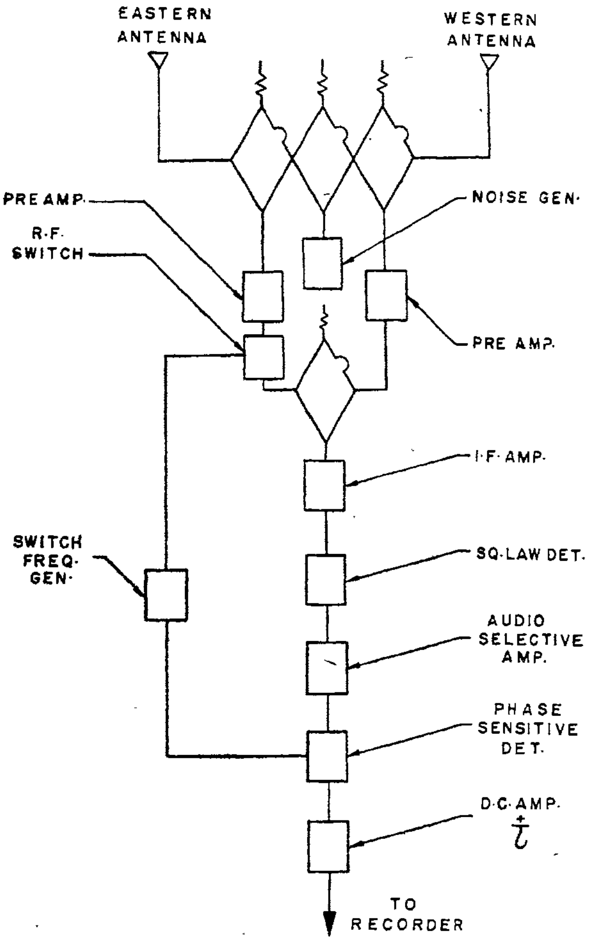

Fig. 1—Block diagram of the receiving system

is of the order of 10 to 12 R. It is also evident that the occultation curve is asymmetric in the sense that the decrease in the fringe amplitudes is more rapid than the recovery. It would appear that there is a significant increase of the intensity on June 11, 1973. This can also be seen from the actual records reproduced in Fig. 3 (a).

4. Discussion

It was shown by Hewish[6] that when radiation having an angular spectrum given by exp $[-(\phi^2/\phi_0^2)]$ is incident on a multiplying interferometer operating at a wavelength λ and with a spacing d the observed fringe amplitude will be proportional to exp $[-(\pi^2 d^2 \phi_0^2/\lambda^2)]$. A comparison of the occulted and unocculted responses of the radio source enables ϕ_0, the scattering angle, to be determined. The scattering angles calculated on this basis from our observations are given in Table 1. It has been suggested that the amount of scattering at smaller angular separations from the sun is a function of solar activity. We have derived the scattering angles from the occultation curve published by Bolton, Stanley and Clark[7]. These

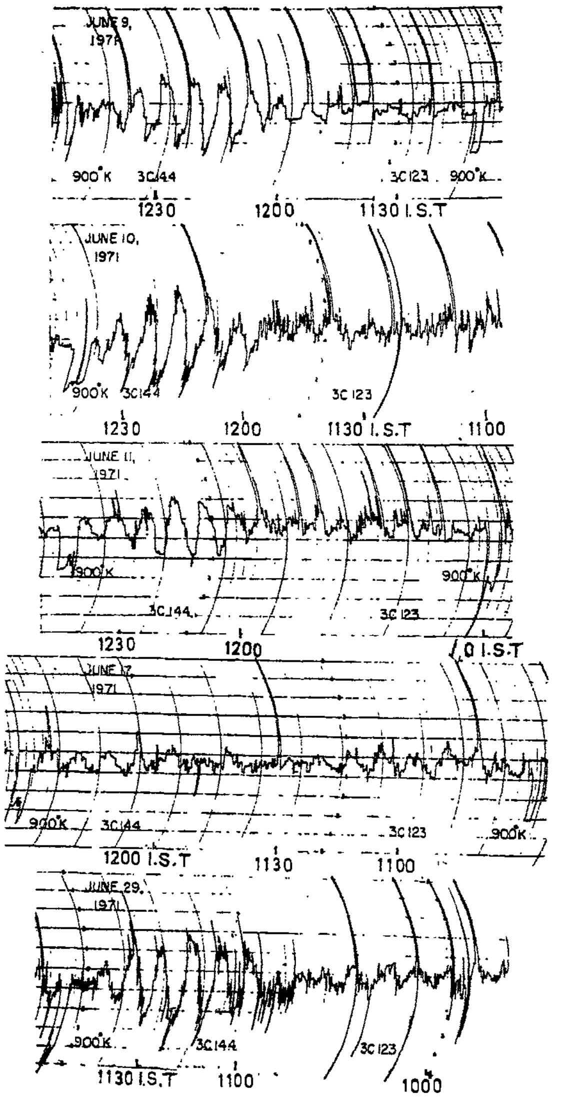

Fig. 2—Records obtained on June 9, 10, 11, 17 & 29, 1971 of the two radio sources 3C 144 and 3C 123

observations were made during 1958 at a wavelength of 12 m with a multiplying interferometer of about 2° fringe spacing. So a direct comparison of the two observations is possible. The scattering angle derived from Bolton *et al.* data is about 50 arc min for angular separations of $\approx 5\ R\odot$. It can be seen from Table 1 that the scattering angle is about the same in 1971 also for the same angular distance. Therefore, it would appear that there is no strong dependence between the amount of scattering and solar activity. Erickson[8] has obtained an empirical relation for ϕ_o between 5 and 60 solar radii based on his occultation observations at 26 MHz:

$$\phi_o = \frac{50\ \lambda^2}{R\odot} \text{ min of arc}$$

where λ is the observing wavelength in meters and $R\odot$ is angular distance. Our data are found to agree with

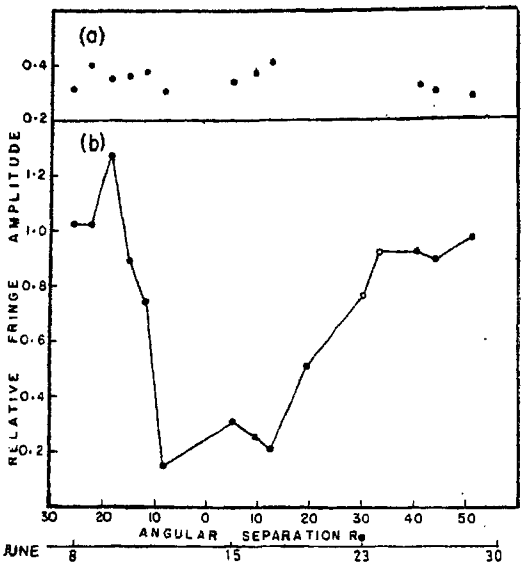

Fig. 3—Variation of relative fringe amplitude during the period June 6 to 30, 1971 obtained using sources (a) 3C 123 and (b) 3C 144

this relation excepting for very close values of $R_\odot$. The asymmetry in the occulation curve can be due to the difference in the structure of the corona along the path of the radio source. This is probably due to the different heliographic latitudes encountered during ingress and egress. Intensity increases of the type observed by us on June 11, 1971 have been previously reported by Gorgolewski, Hanasz, Iwaniszewski and Turlo[9] and Erickson[8]. The simple scattering theory does not explain the increase. Vitkevich[10] showed that an increase can occur if the radiation from Tau. A is focussed by coronal rays acting as cylindrical lenses. An alternate explanation put forward by Gorgolewski *et al.*[9] deals with klystron type of amplification of radio waves by the coronal plasma.

Table 1—Calculated Values of Scattering Angles for Various Angular Distances

Angular Distance in Units of $R_\odot$	Scattering Angles (min of arc)
Ingress	
15	20
12	33
9	81
5	65
Egress	
9	71
12	76
19	50
30	32
44	20
51	10

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