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Coronal Electron Density and the Gradient of Coronal Rotation with Altitude

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Abstract. The calculations of the gradient of coronal rotation period with altitude were performed using electron density model and the radio measurements of solar coronal rotation. The magnitude of the gradient reduces if the emission is at higher harmonics of the plasma frequency. The results seem to reduce the difference in the radio and optical measurements of coronal rotation.

Keywords : Solar Rotation, Coronal Rotation, Electron Density Model, Gradient of Rotation Period

1. Introduction

The solar rotation have been known for the past four centuries, yet there are problems that we do not understand and need more observations and theoretical studies. The solar coronal rotation is even less understood. The recent optical measurements of solar corona (Altrock, 2002) and radio measurements (Vats et al. 2001) are at odds. There are two main differences (1) radio measurements give a lower rotation period than optical measurements and (2) Radio measurements show a systematic variation of rotation period with height (a gradient of coronal rotation) which does not appear to be the case with optical measurements. The radio measurements use electron density model for estimating the height of emission in the solar corona. The present work use electron density model over an extended range, the summary of these calculations and results are given in the next section.

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2. Calculations and Results

The plasma emission produced by the electron beams has been observed in the lower corona up to a frequency of 8.4 GHz (Benz et al. 1992). The detection of plasma emission at such high frequencies requires over dense flux tubes, so that plasma emission can escape in a direction perpendicular to the flux-tube axis, where density scale is much shorter than in a homogeneous corona. Aschwanden and Benz (1995) gave a model of electron density for the type III radio burst and chromospheric evaporation. Their model is a combination of two forms; a power-law function in the lower corona and an exponential form in the upper corona. It is also generally believed that observed emission frequency υ is to be emitted at the s th harmonic of the plasma frequency υ_p (as $\upsilon = s\upsilon_p$).

The radio observations of type III radio bursts in the interplanetary medium have established that the frequency of the radiation were observed to have come from a given height in the solar corona averaging 2 to 5 times the plasma frequency at that height (Steinberg et al. 1984). However, here the calculations are done for s = 1 to 8. The plots for radio emission at different frequencies as a function of height are shown in Fig. 1 (left). This has eight curves, the lowest one is for s = 1 giving the variation of plasma frequency with height. Usually radio emission at plasma frequency is not possible. The emission takes place at the harmonics of plasma frequency, the second. third and so on, curves from below are for s = 2, 3, and so on. The two straight lines drawn parallel to x-axis are for 405 MHz and 2800 MHz. Thus the height of coronal emission at 405 MHz will vary from 4.5×10^4 to 18×10^4 km above the photosphere and that at 2800 MHz will vary from 1.12×10^4 to 3.55×10^4 km.

Vats et al. 1998 showed that the rotational modulation seen in the daily solar radio intensities is due to the fact that this emission consists of two components (1) background emission which could be taken as uniform in the solar atmosphere and (2) localized emission. The localized emission could possibly be due to a summation of large number but individually small type III kind of bursts (Vats et al. 2001). Thus for this localized emission it would be reasonable to use Aschwanden and Benz (1995) model. (Vats et al. 2001) used the observation of nearly simultaneous and continuous recording of radio emission at 10 frequencies in the range of 405 MHz to 2800 MHz. The analysis of these showed that prominent solar rotational modulations exist in all these. The sidereal rotation periods were estimated to be 23.7 days and 24.1 days for 405 MHz and 2800 MHz respectively. The other frequencies in between have a consistently increasing sidereal rotation period (Vats et al. 2001). The radio emission at various frequencies will originate at different height in the solar corona.

3. Conclusions

From the values of rotation period at 405 MHz and 2800 MHz and the height variation from Fig. 1 (left) the gradient of coronal rotation was calculated and it is shown in Fig. 1 (right). Here gradient of coronal rotation period (GCRP) is estimated in the units of msec/km. The magnitude of GCRP decreases as the harmonic number increases. It is around 760 msec/km for second

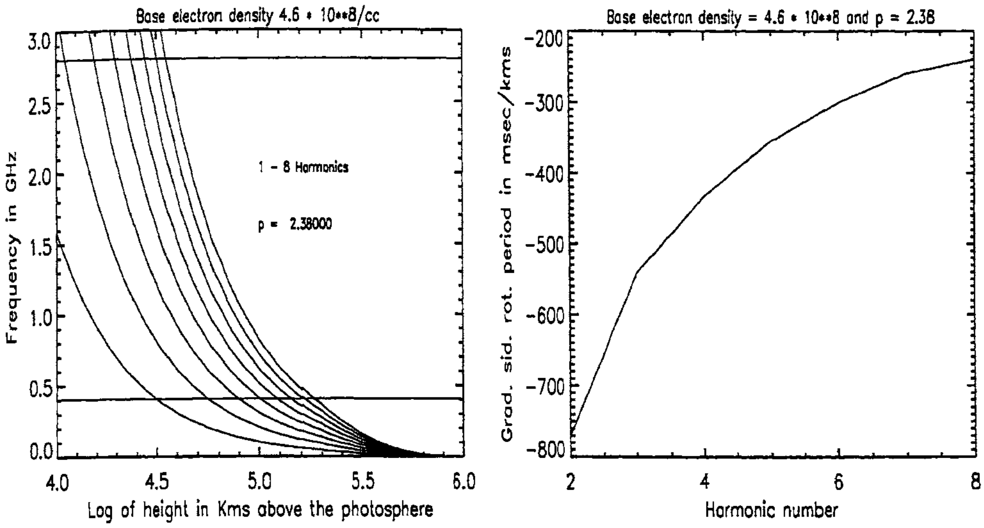

Figure 1. (Left) Showing the variation of emission frequency as a function of height above the photosphere for fundamental frequency and for 2 - 8 harmonics of coronal plasma frequency. Figure 1 (Right) Shows the variation of gradient of sidereal rotation period with harmonic number at which the radio emission has originated.

harmonic and reduces to 240 msec/km for 8th harmonic number. This shows that if the radio emission from solar corona is largely from higher harmonics that will reduce the difference of radio and optical measurements. The optical measurements of solar coronal (Altrock, 2002 and references therein) find no apparent gradient in the coronal rotation with altitude. However, it is worth mentioning here that the radio emission is less likely to be at higher harmonics. There are some indications (Aschwanden and Benz, 1995) that the type III burts are emitted at the fundamental plasma frequency $s = 1$. If this was the case, the gradient of sidereal coronal rotation would have been around 1 sec/km. That would enhance the difference between radio and optical measurements.

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