Coronal Magnetic Field Estimation Using Type-II Radio Bursts

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Abstract Coronal magnetic fields at two different heights were estimated using multiple type-II radio bursts observed on 23 January 2003. The strength of the magnetic field was estimated using 1–5 times the Newkirk density value. With these densities the magnetic field varied from 1.47 to 2.16 Gauss for the first type-II burst, and from 1.13 to 1.76 Gauss for the second one. Its strength was found to have power-law variation with height, with the index varying from −3 to −2 for densities 1–5 times Newkirk's value.

1 Observations, Analysis, Results

Meter-wavelength type-II radio bursts can be used to derive the strength of the coronal magnetic field by relating the speed of type-II radio bursts with the Alfvén velocity. In the so-called multiple type-II bursts, two type-II bursts occur in sequence, the second at lower frequency than the first (Subramanian and Ebenezer 2006).

Type-II emission originates in the vicinity of the transition region of shock waves. For fundamental/harmonic radiation, the properties of the shock across the shock front (up/down stream) are related (Vrsnak et al. 2004), with the density jump related to the instantaneous bandwidth and to the Alfvénic Mach number. The radial velocity can be derived from the drift rate in a type-II burst assuming a density model and radial propagation. The relative bandwidth and Alfvénic Mach number are related as

$$\triangle f/f = (f_u - f_l)/f_l = \sqrt{(N_2/N_1 - 1}, \quad (1)$$

$$N_2/N_1 = 4M_A^2/(3 + M_A^2), \quad (2)$$

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where $M_A = V_r/V_A$ is the Alfvénic Mach number, with V_r the radial velocity of the type-II burst and V_A the Alfvén speed.

Our solar type-II burst data of 23 January 2003 were used to estimate the strength of the magnetic field in the solar corona at two different heights. Figure 1 shows the dynamic spectrum. The first burst started at 04:32 UT around 130 MHz, the second at 05:59 UT around 100 MHz, and so at lower frequency. The relative bandwidths were 0.29 ± 0.03 and 0.39 ± 0.04. The corresponding Alfvénic Mach numbers are 1.46 and 1.67. The drift rate was 0.10 MHz s^{-1} for the first burst and 0.07 MHz s^{-1} for the second. We used Newkirk's density model $N_e = M \times 4.2 \times 10^4 \times 10^{4.32}/\rho$, with ρ measured in solar radii, for the calculation of the burst speed assuming density enhancement factor $M = 1 - 5$. The mean frequencies of the two bursts were 102 and 74 MHz. Magnetic field strengths were estimated from the relation

$$V_A = 1.9 \times 10^4 \times B/f, \tag{3}$$

with B the field strength and f the mean frequency (Dulk and McLean 1978). The variation of the magnetic field with height is shown in Fig. 2. It can be written as a power law of the form $B(R) = \alpha R^{\gamma}$, with the index γ varying between -3 and -2 for density enhancement factors $M = 1 - 5$.

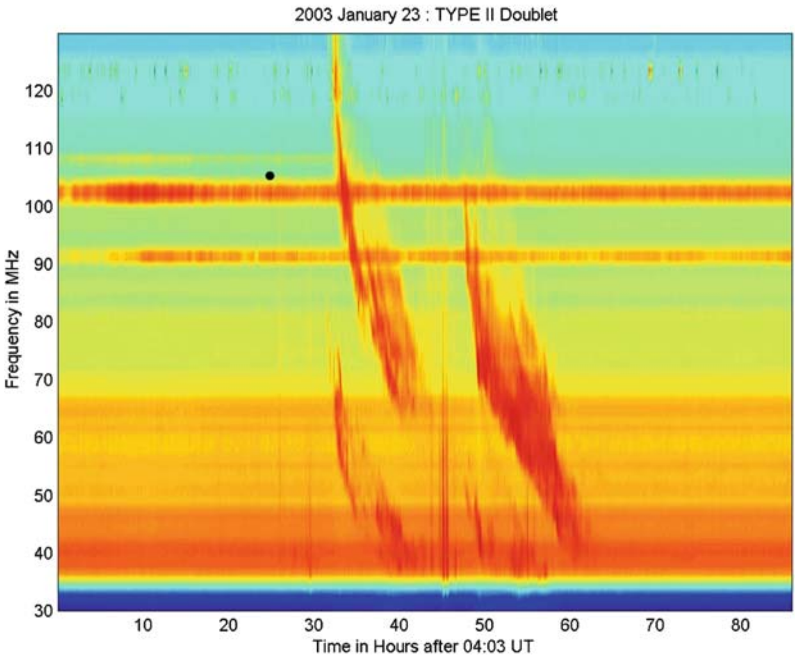

Fig. 1 Example of a multiple type-II radio burst observed with the Gauribidanur digital solar radio spectrograph. Two type-II bursts are seen in sequence: the first one starting at 04:32 UT, the second one at 04:49 UT. Both show fundamental/harmonic structures

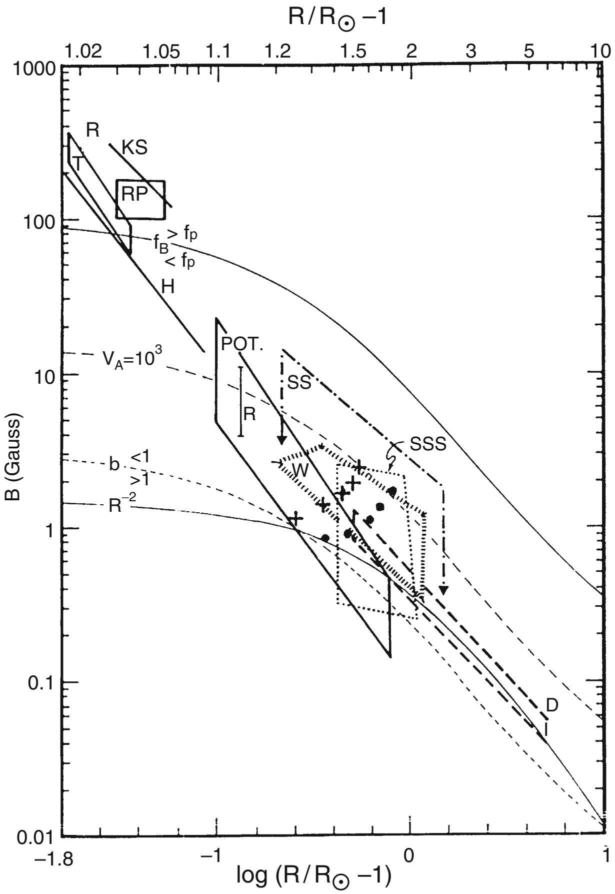

Fig. 2 Variation of the strength of the magnetic field as function of distance to the Sun. The estimated magnetic field values at 102 and 74 MHz are also shown. The *plus* and *filled circle* symbols specify the field strengths for density enhancement factors $M = 1-5$ at 102 and 74 MHz. The emission height and corresponding field strength increase with M at both frequencies

References

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