SUN, SOLAR ACTIVITY AND ASTROBIOLOGY

EVALUATION OF CORONAL SHOCK WAVE VELOCITIES FROM THE II TYPE RADIO BURSTS PARAMETERS

V.V.Galanin[1], E.A.Isaeva[1,2], R.O. Kravetz[1]

[1] Institute of Radio astronomy of NAS of Ukraine, URAN-4 observatory
[2] Astronomy observatory institute of I.I.Mechnikov ONU
Odessa, Ukraine
[1] gvv@breezein.net, [1,2] isaeva-ln@mail.ru

ABSTRACT. The work presents the results of research of connection between the coronal shock waves and the parameters of type II (mII) meter-decameter bursts in 25-180 MHz band for 66 solar proton events. The velocities of coronal shock waves for this two cases where determined. In the first case the velocities of the shock waves was evaluated according to the Newkirck model and in the second case – directly from the type II radio burst parameters. The calculated values of shock waves velocity was compared with the same velocity values that is published on NGDC site. The comparative analysis showed that precision of coronal shock waves velocity estimation which gets directly from type II radio bursts parameters was higher than the same one which used the Newkirck model. Research showed that there is exist the sufficiently strong connection between the shock wave velocity and the delay of type II burst intensity maximum on the second harmonica. Correlation coefficient between the studied parameters was equal to ≈ 0.65.

Key words: shock speed, drift velocity

1. Introduction

It is well known that solar proton events (SPE) have great influence on the space weather. An SPE which is accompanied with streams of high energy particles, coronal mass ejections (CME) and shock waves are cause some geoeffects (Pudovkin et. al., 1992; Rivin, 1985). In this connection it is expedient to evaluate beforehand an intensity of high energy particle streams, velocity of CME and shock waves before it is reach the Earth orbit. It can be easy done by the radio burst parameters (Mel'nikov et. al., 1991; Chertok et. al., 2009). In this paper we examine the estimation of coronal shock waves (CSW) velocity. It is considered that shock waves in solar corona can be generated either in the energy output burst region (Classen et. al, 2002) or upon CME movement (Gopalswamy et. al., 1998). Most reliable indicator of shock waves in solar corona is type II radio bursts. It is considered that plasma mechanism of radio bursts (Cairns et. al., 2003) is responsible for it generation.

2. Rezults

For the analysis we have used the original dynamic spectra records obtained on Solar Radio Spectrograph (SRS) in 25-180 MHz range (http://www.ngdc.noaa.gov/stp/space-weather/solar-data/solar-features/solar-radio/rstn-spectral/). Fig.1 show an example of dynamic spectrum of proton event type II burst 31.05.2003. As it seen we can distinguish two bars corresponding to main and second harmonic. They are approximated good enough by the functions (1) (light lines on fig.1)

$$\lg f_{i,j} = k_j \cdot \lg t_i + d_j \quad (1),$$

where t_i - time of maximum intensity of type II burst on the $f_{i,j}$ frequency, k_j and d_j - coefficients of linear regression, i=1,2..n – counting number, j=1,2 – number of harmonic. Zero point of time counting for all events has corresponded to the beginning of the first harmonic on 180 MHz frequency.

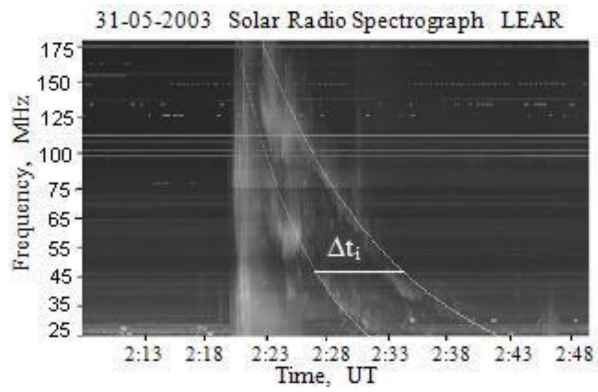

Figure 1: An example of dynamic spectrum of proton event type II burst 31.05.2003.

Main frequency of plasma radiation f is proportional to electron density $Ne^{0.5}$ (2)

$$f_{i,1} = \sqrt{\frac{e^2 N_e}{\pi m_e}} = 8.98 \times 10^{-3}\sqrt{N_e} \quad \text{MHz} \quad (2)$$

So, using empirical dependence of frequency from time $f_{i,j}$ (1) and suitable model of coronal electron density we can calculate heights and velocities of type II radio burst sources. To find the height distribution of electron density we had use the Newkirck model (3) (Newkirk, 1961):

$$N_e = N_0 \times 10^{4.32 R_\odot / R} \quad (3),$$

where N_0=4.2×10^4 cm^{-3} - concentration, $R_\odot$ - solar radius, R - distance from solar center to source of type II burst.

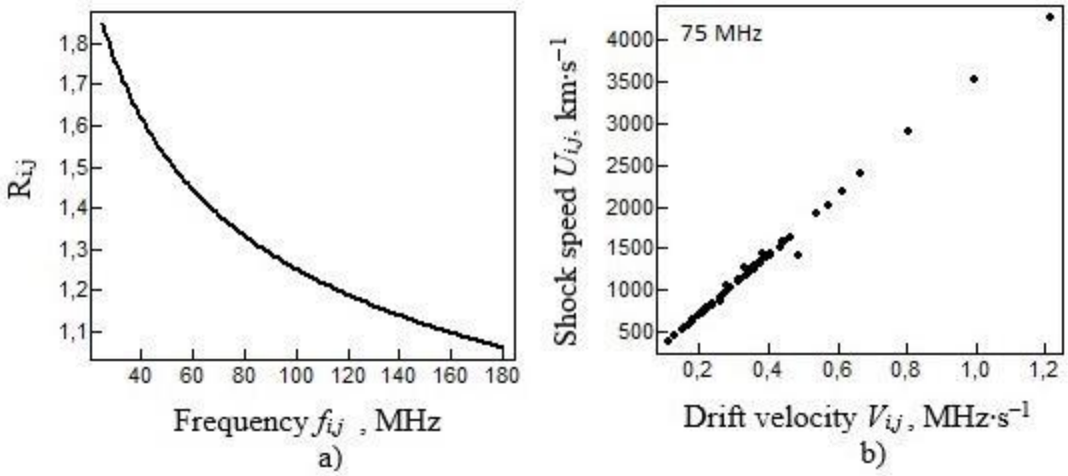

Figure 2: a). Relationship between the frequency $f_{i,j}$ and the height $R_{i,j}$ of source of type II radio burst
b). Relationship between the drift velocity $V_{i,j}$ and the shock speed $U_{i,j}$

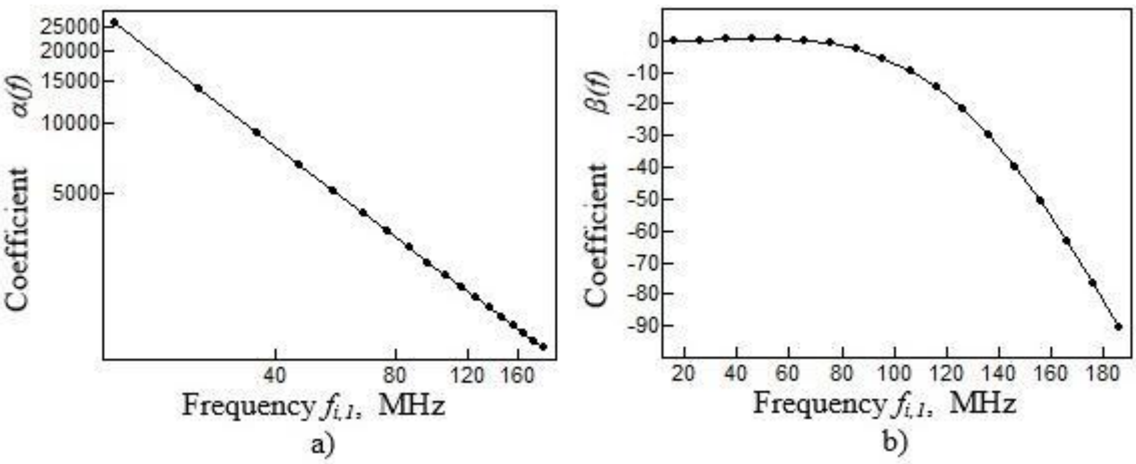

Figure 3: The dependence of linear regression coefficients $\alpha(f_{i,j})$ and $\beta(f_{i,j})$ (5) from frequency $f_{i,j}$.

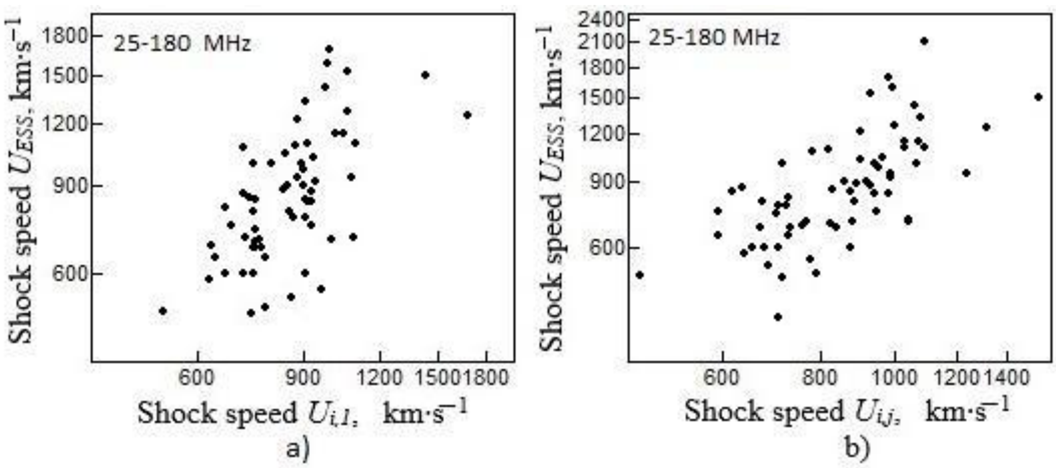

Figure 4: Disperse diagram of calculated velocity values $U_{i,j}$ and U_{ESS}:
a). $\lg U_{i,1} = 0.3335 \cdot \lg ((R_{i+1,j} - R_{i,j})/(t_{i+1,j} - t_{i,j})) + 3.2758$, $r\,(U_{i,1}, U_{ess}) \approx 0.56$
b). $\lg U_{i,j} = -0.2408 \cdot \lg \Delta t_i + 3.2758$, $r\,(U_{i,j}, U_{ESS}) \approx 0.65$

Thus, when determine the electron density from formula (2) and using model (3) we can determine the height $R_{i,j}$ of source in the given time moment t_i and hence the velocity of shock wave $U_{i,j}$. As the result of the research it was ascertain that there is exist the clear connection between the frequency $f_{i,j}$ and the height $R_{i,j}$ of source of type II radio burst, and also between the shock wave velocity $U_{i,j}$ and drift velocity $V_{i,j}$ in the given time moment. Fig. 2 a) show dependence between $f_{i,j}$ and $R_{i,j}$, fig,2 b) – between $U_{i,j}$ and $V_{i,j}$ on 75 MHz frequency for all of 66 proton events.

More detailed research has shown, that dependence between $f_{i,j}$ and $R_{i,j}$ was found approximately identical for all of 66 events (4), but dependence between $V_{i,j}$ and $U_{i,j}$ was found more complex because there is exist the strong dependence of linear regression coefficients $\alpha(f_{i,j})$ and $\beta(f_{i,j})$ (5) from frequency $f_{i,j}$ fig. 3 a) and b).

$$\lg R_{i,j} = -\alpha \cdot \lg f_{i,j} + \beta \quad (4)$$

$$\lg U_{i,j} = \alpha(f_{i,j}) \cdot \lg V_{i,j} + \beta(f_{i,j}) \quad (5)$$

Thus, it is enough to know the dependence of frequency from time (1) and also the dependence of height of type II burst source from frequency (4) to evaluate the velocity of shock wave in any given time moment (6).

$$U_{i,j} = (R_{i+1,j} - R_{i,j})/(t_{i+1,j} - t_{i,j}) \quad (6)$$

Calculated values of velocity $U_{i,j}$ we have compare with the values of coronal shock wave velocities U_{ESS} which is publish on NGDC site in 25-180 MHz range (http://www.ngdc.noaa.gov/stp/space-weather/solar-data/solar-features/solar-radio/radio-bursts/tables/spectral-sgd/) .

Fig. 4a) show disperse diagram of this values. Correlation coefficient r between this values was found low: $r\ (U_{i,j},V_{i,j}) \approx 0.56$. It is testified that Newkirck model (Newkirk, 1961) is not allow to evaluate quite exactly the velocity of coronal shock waves. That is why we had performed the research of relationship directly between U_{ESS} and type II radio burst parameters. As the parameters which is characterizes the velocity of shock wave we used such parameters as the velocity of frequency drift $V_{i,1}$ and $V_{i,2}$ on first and second harmonics, relative distance b_i between harmonics on the dynamic spectra in the given time moment (Tsap and Isaeva, 2013) and time delay Δt_i (7) of intensity maximum of type II burst on second harmonic relatively first one on the given frequency $f_{i,j}$ (fig.1).

$$\Delta t_i = t_{i+\Delta t,2} - t_{i,1} \quad (7)$$

Comparative analysis showed that the strong enough relationship between time delay Δt_i and U_{ESS} exist. Correlation coefficient between Δt_i and U_{ESS} was equal $\approx$ 0.65, that is somewhat high then between $U_{i,j}$ and U_{ESS} (fig. 4b). In the same time, relationship of U_{ESS} with drift velocities $V_{i,1}$ and $V_{i,2}$ was found approximately the same as the relationship between $U_{i,1}$ and U_{ESS} that is correlation coefficient is equal ≈ 0.56.

3. Conclusions

Evaluation of coronal shock waves velocity that use Newkirck model and directly from type II radio burst parameters has reveal some interesting peculiarities. So, using Newkirck model it was show that clear dependence between frequency and height of type II burst radio source exist. Also dependence between drift velocity and shock wave velocity exist. Presence of such dependencies indicates that it is possible to evaluate coronal shock waves velocity directly from type II radio burst parameters. Confirmation of this is the strong enough dependence between shock waves velocity which is published on NGDC site and time delay of type II burst maximum on the second harmonics relatively first one on the given frequency $f_{i,j}$.

References

Cairns I.H., Knock S.A., Robinson P.A., Kuncic Z.: 2003, *Space Sci. Rev*., **107**, 27.

Classen H.T, Aurass H.: 2002, *Astro. And Astrophys*., **384**, 1098.

Chertok I.M., Grechnev V.V. and Meshalkina N.S.: 2009, *Astron. Zh*., **86**, 1133.

Gopalswamy N., Kaiser M.L., Lepping R.P., Kahler S.W., Ogilvie K. et. al.: 1998, *J. Geophys. Res*., **103**, 307.

Mel'nikov V.F., Podstrigach T.S., Daibog E.I. and Stolpovskii V.G.: 1991, *Kosm. Issled*., **29**, 95.

Newkirk G.: 1961, *Astrophys. J.*, **133**, .983.

Pudovkin M.M., Raspopov O.M.: 1992, *Geomagnetism and Aeronomy*, **32/5**, 1.

Rivin Yu.R.: 1985, *Geomagnetism and Aeronomy*, **25/6**, 990.

Tsap Yu.T. and Isaeva E.A.: 2013, *Cosmic Reseach*, **51/2**, 108.