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Coronal loops diagnostics using the parameters of U-burst harmonic pair at frequencies 10-70 MHz

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Abstract

The results of the first observations of solar sporadic radio emission using one section of the new being currently created Giant Ukrainian Radio Telescope (GURT) are presented. The parameters of inverted U-burst with harmonic structure observed with GURT are considered. The main attention is paid to the time delay between the fundamental and harmonic components. The analytical model explaining the observed time delay is proposed.

1. Introduction

Solar U-bursts are known since 1958 [1] and are considered as variety of normal type III burst. This mechanism supposes the electromagnetic waves generation not only at the local electron plasma frequency but also at doubled fundamental or harmonic frequency. From the theoretical viewpoint the instant ratio between the harmonic and fundamental frequencies should equal 2 [2]. Nevertheless many observations of different types of solar bursts show that this ratio lies between 1.6 and 1.8 and always less than 2 [3]. In our opinion one of the reasons of this effect can be the time delay of the fundamental emission with respect to the harmonic one. The shape of type III dynamic spectra does not allow finding the time delay between the harmonic pair components. From this point of view type U bursts give a unique possibility to determine the above time delay since these bursts have specific point on the dynamic spectrum – the turning point. In this paper we report the results of observation of the solar U-bursts harmonic pair. The burst was registered during first observations conducted with one section of new Giant Ukrainian Radio Telescope (GURT) [4] on 8 August, 2012.

2. Observations

The radio telescope GURT is currently constructed near the existing radio telescope UTR-2 in the frames of National Academy of Sciences of Ukraine target program. The section is a square active antenna array consisting of five rows and five columns oriented along East-West and South-North directions respectively, or 5x5 cross-dipoles.

Figure 1: GURT section.

The individual dipoles are spaced by 3.75 m from each other along both rows and columns. All dipoles are mounted at 1.6 m above the ground and oriented at 45° to the meridian. Among all observed bursts the U-burst, recorded on 8 August 2012 was of especial interest. This burst had well developed descending branch and was observed both in fundamental and harmonic emission. The turning frequencies of the U-burst harmonic components were 25 and 50 MHz respectively (Fig. 2).

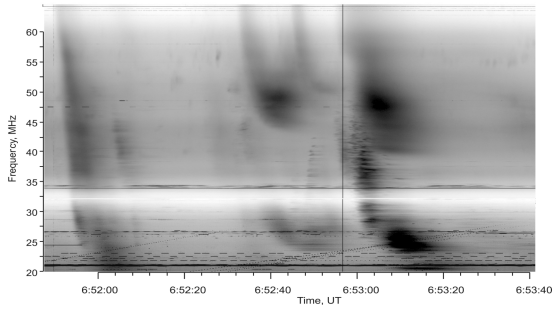

Figure 2: U-burst with harmonic structure.

The frequency drift rate of ascending branch of the fundamental and harmonic components of the burst equaled -2.5 MHz/s and -7 MHz/s respectively that corresponds to the emission source velocity of (0.11-0.12)***c***, where ***c*** is the speed of light.

3. Discussion

Observations show that fundamental component arrives to the observer's place in 7.5 s later than the harmonic one. Since according to the plasma emission mechanism both components are generated simultaneously and at the same place the observed time delay could only arise during the emission propagation from the source to the observer. In the proposed model the source of the burst is located inside high magnetic loop containing plasma of increased density and/or temperature. Under such conditions the time delay of the fundamental emission will be formed during its propagation from the source to the loop boundary, i.e. in regions where the group velocity of the electromagnetic wave of the fundamental component is much less than the speed of light. In general the time required for electromagnetic wave to travel from the source to the loop boundary is defined by the equation

$$t = \int_{R}^{R1} \frac{dr}{V_{ep}(R,r)}, \qquad (1)$$

Where R is the height of the top of the loop center, R1 – height of the upper boundary of the loop, V_{ep} – electromagnetic wave group velocity and r – current coordinate of the electromagnetic wave.

Supposing that the plasma density profile inside the loop follows the barometric law we derive the analytical expression of the time delay of the fundamental component with respect to the harmonic one. From the obtained equation we conclude that the time delay between the harmonic components is determined by the relation between the loop height and the plasma temperature at the top of the loop. Thus for the observed delay of 7.5 s the loop height and the plasma temperature inside the loop are connected as follows

$$R_1^2 \cdot T_1 \approx 60 \qquad (2)$$

where R_1 is the loop height normalized to the solar radius and T_1 is the plasma temperature normalized to the 10^6 K. Since in the analyzed period of time COR2/STEREOA coronagraph showed visible loop structure that was as high as 5 solar radii, the observed time delay indicates that the plasma temperature inside the loop is about $2.4 \cdot 10^6$ K.

4. Summary and Conclusions

The results of the first observations with one section of the GURT radio telescope prove that the existing section can be already used for the broadband monitoring and registration of the solar sporadic radio emission in the decameter and meter wavelengths band. Proposed analytical model can be used for the diagnostics of the plasma inside high coronal loops.

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