RADIO-ASTRONOMY

SEARCH FOR THE THIRD HARMONIC OF TYPE III BURSTS RADIO EMISSION AT DECAMETER WAVELENGTHS

Brazhenko A.I. [1], Melnik V.N. [2], Konovalenko A.A. [2], Pylaev O.S. [2], Frantsuzenko A.V. [1], Dorovskyy V.V. [2], Vashchishin R.V. [1], Rucker H.O. [3]

[1] Poltava gravimetrical observatory of Institute of geophysics, National Academy of Sciences of Ukraine, Poltava, Ukraine
[2] Institute of Radio Astronomy, National Academy of Sciences of Ukraine, Kharkov, Ukraine
[3] Space Research Institute, Austrian Academy of Sciences, Graz, Austria

ABSTRACT. The results of observations of trio bursts consisting of type III bursts are presented in this paper. The instantaneous frequency ratio of trio components is near 1:2:3. We analyze flow, duration, frequency drift rate and polarization of trio components as well as dependencies of these characteristics on frequency.

Key words: type III bursts, drift rate, duration, polarization, second harmonic, third harmonic, decameter wavelength range…

The third harmonic is not usually observed in the solar type III (and associated with them) radio bursts. So new papers, reporting about registration of the third harmonic bursts, are very important for progress in theoretical aspects of researching solar corona. Detection of the third harmonic of type III bursts radio emission at decameter wavelengths can be useful for giving more precise definition to the plasma mechanism of emission and for accuracy of solar plasma parameters on relevant altitudes.

There are some records of the third harmonic in literature. Here we note a powerful U-burst recorded by Haddock and Takakura: their dynamic spectrum, presented in the monograph by Kundu (1965), shows a weak fundamental and intensive second and third harmonics. Another example is a type V burst observed by Benz (1973). Some features of dynamic spectrum of the burst are duplicated at 1.5 times higher frequencies. This indicates the presence of radio emission corresponding to the second and to the third harmonics. Also we point to numerous records of the J- and U-bursts made by Stewart (1962). Frequency ratio of that bursts lies in range 1.5-1.7. The radiation mechanism of the third harmonic was developed by Zheleznyakov & Zlotnik (1974). Afterwards this theory was improved by its authors and other scientists. For example there are papers by Takakura (1974) and Kliem (1992) based on the observations of J-bursts with frequency ratio 2:3 and the third harmonic of type II burst correspondingly. Also there are other observations of the third harmonic of type II bursts (Zlotnik 1998, Dorovskyy 2007). Only last paper refers to decameter wavelength range. Investigating the higher harmonics (Cairns 1988, Yoon 2003, Yi 2007, Rhee 2009), authors analyze similar radiation mechanisms.

Radiation mechanism

Type III radio bursts occur by so-called plasma emission. Their source is electron beam propagating along open magnetic field lines in upward direction. The propagation of electron beam through coronal plasma generates Langmuir waves (l) that can transform into escaping electromagnetic transverse waves (t) by number of processes. Fundamental plasma emission (first harmonic, t_I) results from scattering of Langmuir waves by thermal ions (i) near the local plasma frequency:

$$l + i \to t_I + i\,.$$

The second harmonic (t_{II}) of type III bursts occurs by coupling two Langmuir waves:

$$l + l \to t_{II}\,,$$

or by coupling Langmuir wave with fundamental transverse wave:

$$l + t_I \to t_{II}\,.$$

It is evidently that the second harmonic radiates on double local plasma frequency.

So, the third harmonic radio emission is generated on the triple electron plasma frequency by interaction of three Langmuir waves:

$$l + l + l \to t_{III}\,,$$

or by interaction of Langmuir wave and transverse wave of the second harmonic:

$$l + t_{II} \to t_{III}\,.$$

Observations

The bursts, we analyze in this paper, were registered during summer observations in 2011 and 2012 with the radio telescope URAN-2. It is one of the biggest radio telescopes of decameter wavelength range (effective square is 28000 m^2). URAN-2 can receive two linear (circular) polarizations. Spectrograph DSPz allows registering radiation with frequency resolution 4 kHz and time resolution 10 ms in a whole frequency band 8 – 32 MHz (or in a part of it).

We registered 12 trio composed of a combination of type III and type IIIb bursts. Observations were made in a frequency band 8 – 32 MHz with time and frequency resolution 100 ms and 4 kHz correspondingly. Example of trio consisting of IIIb-IIIb-III bursts is shown on Figure 1. We find such regularities in a structure of trio bursts: the first component was a type IIIb burst mostly, the second component was a type III burst as well as type IIIb burst, the third component was a type III burst in the most cases. Moreover, type III burst was the first component of trio only in a combination III-III-III, and type IIIb burst was the third component only in a combination IIIb-III-IIIb.

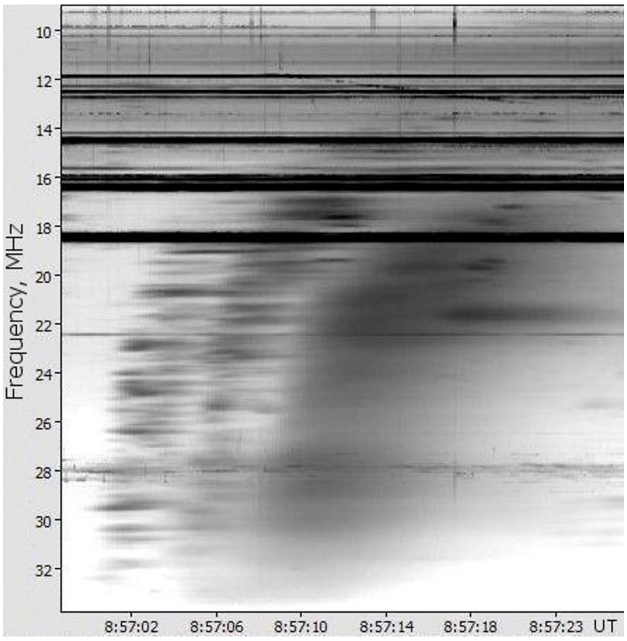

Figure 1: Example of trio.

We simulate an “average” trio for more clearly understanding the characteristic properties. The measurements of burst features, averaging in 4 MHz intervals, will be presented further.

Polarization

We find that components of each trio have the same sign of polarization. Polarization of type IIIb bursts is high, registered value is up to 60-70%. Type III bursts have smaller polarization, registered value is up to 10-20%. Polarization of the first component is always the highest in trio bursts. In addition there is a trend that the third component of trio has smaller polarization then second component (for the same type bursts).

Duration

We register duration at the level of 0.9-power, because measurements of duration were impossible at half-power level. We recalculate 0.9-power duration to half-power duration supposing that the form of burst is Gaussian. The values we derive for type III bursts vary from 2.3 s to 15 s. The most number of values concentrates in interval 5 – 10 s. The type IIIb bursts have always smaller duration at the same frequencies: from 0.5 s to 7 s. The majority of values lies in range 1.3 – 5 s.

Moreover we obtain that duration of bursts increases with decreasing of frequency. Figure 2 shows this dependency for “average” trio.

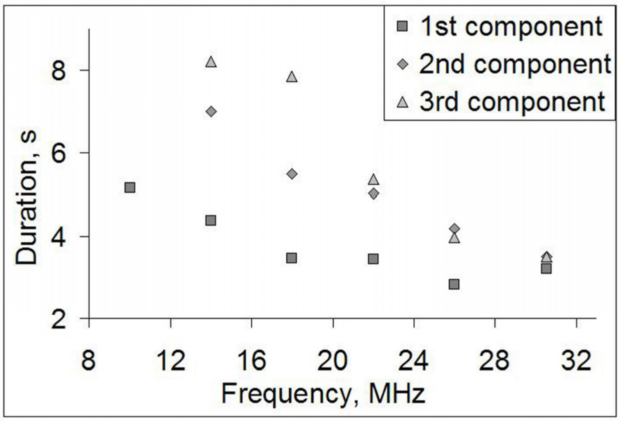

Figure 2: Average duration of trio components dependencies on frequency. Grey marks are results of measurements, that were averaging over all trio in proper frequency band

Frequency drift rate

The emission of all bursts in all registered trio drifts rapidly from high to low frequencies. The frequency drift rate decreases with decreasing frequency, its values vary from 1.1 MHz/s to 4.4 MHz/s. We find the drift rate dependence on frequency is linear:

$$df/dt = -bf \, .$$

The value of factor b lies in interval from 0.07 to 0.18. Such results are confirmed by some papers (Wild, 1950; Melnik & Boiko, 2011), whose authors independently obtain similar proportional coefficient. The factor b indicates the size of coronal inhomogeneity over the active region. The linear dependency of drift rate on frequency is evidence of exponential corona (Melnik & Boiko, 2010).

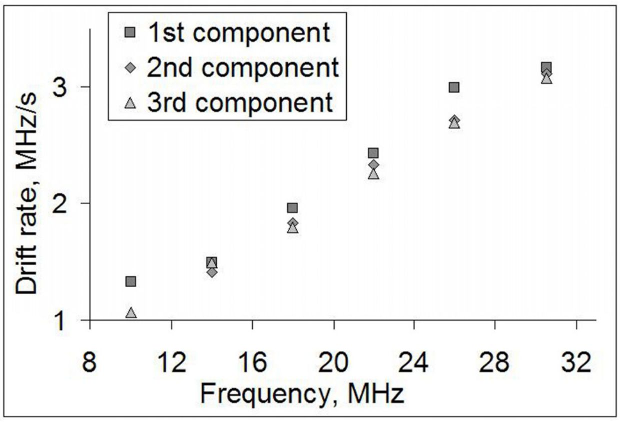

Figure 3: Average drift rate of trio components dependencies on frequency. Grey dots are results of measurements, that were averaging over all trio in proper frequency band.

Drift rate of different components of a trio differ a little in equal frequency intervals: average deviation is near 10%. Average drift rate of the first trio component is more than others. And the second trio component tends to drift faster than the third component. Figure 3 shows how drift rate of trio components depends on frequency.

Instantaneous frequency ratio

Many bursts were not visible at low frequencies through disturbances and influence of ionosphere. Therefore we have to simulate bursts to calculate the instantaneous frequency ratio.

To estimate a frequency ratio of trio components we approximate bursts (maximum flow of bursts) with different functional dependencies. The most correct model is described by the exponential function:

$$f = ae^{-bt},$$

where f – frequency, t – time of maximum flow from the beginning of the observation, a, b – coefficients calculating by the least-squares method. This conclusion is confirmed by the derived results about linear dependence of drift rate on frequency:

$$f = ae^{-bt}, \; {df}/{dt} = -abe^{-bt} = -bf \; .$$

We obtain the instantaneous frequency ratio of trio components by averaging frequency ratio in points of time interval in which simulated trio arranges in frequency band 8 – 32 MHz (see Figure 4). Instantaneous frequency ratio of maximum flow of the first and the third "average" trio components is ${f_3}/{f_1} = 2.7$. The third trio component occurs at a 1.5 times higher frequency than second component: ${f_3}/{f_2} = 1.5$. The frequency ratio of the second and first trio components is ${f_2}/{f_1} = 1.8$, it is confirmed by the theoretical and observational papers about the second harmonic.

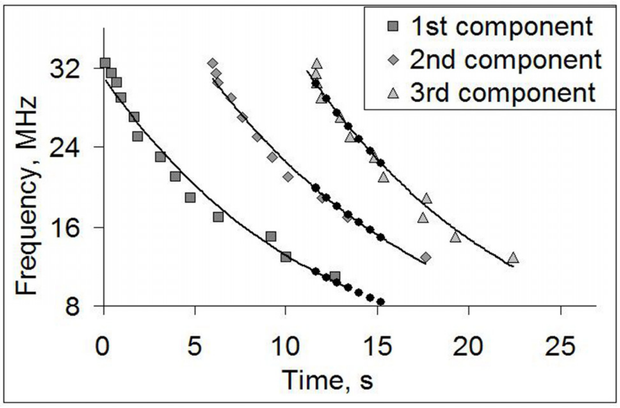

Figure 4: Approximation of trio. Grey points are average observed values of maximum flow. Curves present exponential model of bursts. The frequency ratio of trio components was calculated in black points.

So, there are a number of reasons that allow us to assert that registered trio components have harmonic relations:

1) polarization of the first component of trio is always higher than others; it is up to 60 – 70%, that corresponds to the generally accepted viewpoint about the first harmonic emission;

2) the second and the third components of trio have polarization (10 – 20%), that is typical for the second and the third harmonics according to the plasma radiation mechanism;

3) instantaneous frequency ratio is near to 1:2:3.

References

Kundu M.R.: 1965, *Solar Radio Astronomy*, Interscience Publ., New York.

Benz A. O.: 1973, *Nat. Phys. Sci.*, **242**, 39.

Stewart R.T.: 1962, *CSIRO Division of Radiophysics Report RPR*, **142**.

Zheleznyakov V.V., Zlotnik E.Ya.: 1974, *Solar Phys.*, **36**, 451.

Takakura T., Yousef S.: 1974, *Sol. Phys.*, **36**, 451.

Cairns I. H.: 1988, *J. Geophys. Res.*, **93**, 858.

Kliem B., Kruger A., Treumann R. A.: 1992, *Sol. Phys.*, **140**, 149.

Yoon P.H., Gaelzer R., Umeda T., Omura Y., Matsumoto H.: 2003, *Phys. Plasmas*, **10**, 364.

Yi S., Yoon P.H., Ryu C.-M.: 2007, *Phys. Plasmas*, **14**, 013301.

Tongnyeol Rhee, Chang-Mo Ryu, Minho Woo, Helen H. Kaang, Sumin Yi, and Peter H. Yoon: 2009, *Astrophys. J.*, 694:618 625.

Zlotnik E.Ya., Klassen A., Klein K.-L., Mann G.: 1998, *A&A*, **331**, 1087.

Dorovskyy V.V., Mel'Nik V.N., Konovalenko A.A., Rucker H.O., Abranin E.P., Stanislavsky A.A., Le-cacheux A.: 2007, *European Planetary Science Con-gress*, 688.

Wild J.P.: 1950, *Aust.J.Sci.Res.*, **3**, 541.

Melnik V.N., Konovalenko A.A., Rucker H.O., Boiko A.I., Dorovskyy V.V., Abranin E.P., Lecacheux A.: 2011, *Solar Phys.*, **269**, 2.

Boiko A.I., Mel'nik,V.N., Konovalenko A.A., Rucker H.O., Abranin E.P., Dorovskyy V.V., Lecacheux A.: 2010, *PRE VII*, 367.