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TYPE II BURST HIGH TIME RESOLUTION AND POLARIZATION CHARACTERISTICS AT FREQUENCIES HIGHER THAN 200 MHz

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Abstract

Some new results based on high time resolution and polarization studies of solar type II radio bursts are presented. It is found that the fine structures are present in some events whereas they are completely absent in few other cases. The fine structures generally appear at the beginning of an event. The polarization remains constant during the entire event. Fine structures are upto 15% more polarized than the continuum (backbone) and the sense is the same for both. Sometimes the continuum can also be highly polarized. Experimental data are in good agreement with the proposed theory.

Introduction

Type II solar radio bursts are characterized by a slow drift from higher to lower frequencies (~ 1 MHz/s), starting frequency normally ≈ < 150 MHz (sometimes upto 400 MHz) and duration a few minutes. Type II bursts are generally considered as the radio evidences of collisionless magnetohydrodynamic shock waves since the frequency drift corresponds to the shock speeds in the corona when the appropriate density model for the corona is used. And also these bursts are characterized by the narrow bandwidth of the drifting "ribbons", the simultaneous occurrence of the fundamental and second harmonic emission (which is also a signature of plasma emission mechanism) and the band splitting ($\Delta f/f$ = 0.1 ÷ 0.3). The brightness temperature can range from 10^{10}K to 10^{13}K.

Drifting bands or lanes and herringbone structures are usually called fine structures. These structures are usually superposed on the continuum (backbone). Lanes are neither harmonically related nor consistent with simple band splitting. They are supposed to be produced by distinct disturbances propagating through the coronal inhomogeneities. The duration of these fine structures is ~ 0.2s. Evident herringbone structures are relatively rare (see Slottje 1981). There are positively drifting bursts (duration ~ 0.2 s) at the high frequency side of the backbone as well as negatively drifting bursts at the lower frequency side. For more details see Krueger (1979) and Nelson and Melrose (1985).

Time Profile and Polarization at Single frequencies

Our interest is confined mainly to the study of the type II burst high time resolution profiles and polarization at single frequencies (237, 327 and 408 MHz), for which we have selected 13 type II events. This is the first time that a systematic study is done using high time resolution (time constant ~ 0.03 s) and polarization profiles of type II bursts at fixed frequencies. It is not possible to follow the detailed profiles of an event in the case of spectral data due to low film dynamics and generally low time resolution.

Type II bursts recorded at single frequencies show a "continuum" (in spectral observations it is normally called backbone). Generally it consists of different blobs, each of them lasting for a few seconds.

The intensity of a burst increases with decreasing frequency in the above mentioned range of frequencies whereas the intensity of the fine structures which are superposed on the continuum remains constant at all frequencies. Usually the intensity of the fine structures is less than or equal to that of the continuum peak; single components lasts ≈ 0.2 s.

We divide the type II events in two categories "A" and "B" corresponding respectively to the presence or absence of fine structures. Sometimes the same event can show both the categories, in which case there is a smooth transition between them. Figures 1 and 2 are the typical examples of such events. The "A" configuration is observed in the beginning of the event while the "B" shows up in the latter part of the burst. The "A" type configuration is the most common in our data. This may be severely biased by our rather high observing frequencies. The "B" structures show at the top of the continuum very short ($\sim < 0.1$s) irregular spikes; They do not coincide in both the polarimetric channels at the same frequency. Their intensity is less than the continuum peak by an order of a magnitude (0.03 ÷ 0.08). Such structures resemble very much the ones at the top of a type III burst.

Regarding polarization of type II bursts and their fine structures, it is very difficult to say whether the emission is at fundamental or at second harmonic from our records nonetheless we are sure about two events of our selection that they are at the second harmonic (June 10, 1981 and February 16, 1984) since it is confirmed by the spectral data in which both fundamental and harmonic are present. For both the events the continuum is unpolarized whereas the fine structures of the first event are 15% polarized (R-handed; extraordinary) and those of second event are unpolarized. Due to reduction problems, the polarization upto 5% is considered as zero and the remaining values are rounded off to the mutiples of 5%. For the remaining 11 examples where only one band is observed in the spectrum, it is difficult to ascertain whether the emission is at fundamental or at harmonic. Most probably it is harmonic, since it easily escapes from the source region. However it is interesting to note that the event with the highest observed polarization (80% for the fine structures and 70% for the continuum; Dec 18, 1982 event) corresponds to the ordinary emission giving a clue that it is the fundamental. For these 11 events, we have found the corresponding positions of the associated flares using Solar Geophysical Data bulletin. According to the magnetic field of the major spot nearby the flare position, we confirm the ordinary emission in three cases and extraordinary for two examples. Occasionally we could be able to discriminate between fundamental and second harmonic events but in such cases the fundamental is always polarized in ordinary sense and the harmonic is in extraordinary mode.

The continuum (backbone) is unpolarized in 70% of the cases and fine structures are unpolarized in 54% of the cases - (see Fig.3). In a given event the continuum as well as the fine structures are polarized in the same sense. The continuum generally is less polarized, however the difference between the two polarizations is 15% at maximum. This means that the continuum can also be rather highly polarized.

It is important to note that the polarization is maintained substantially constant during the whole event: measurements at the same and at different frequencies of a given event show values for different single fine structures during the same blob differ at maximum by 20%. These polarization properties are very remarkable when we remember the huge dimensions of type II bursts (Nelson and Melrose 1985).

The spectrum of the December 18, 1982 event is very similar to the one of February 9, 1982; in particular both are narrow banded (~ 50 MHz , sometimes also less) but as regards the polarization the first one is strongly polarized, the other one is unpolarized. The location of the first event was near the disk center, the other one was localized near the limb. These results show that the polarization is independent of the spectral characteristics, also the position on the disk of the associated flares does not influence the polarization of the events. There is also no connection between the starting frequency and polarization.

The frequency drift we were able to measure was in the range 3 ÷ 9 MHz/s, which is a little more than normally reported; the difference is due to the rather high frequency range we observed.

Theory

Using ISEE-3 observations it was found that the majority of interplanetary shock waves are supercritical and quasi-perpendicular. A supercritical shock is characterized by $M = V/V_A > 2$ (in the corona $V_A \sim 400$ km/s). Recently Krasnoselskikh et al (1985), Thejappa (1986, 1987) have developed a self-consistent theoretical model for type II radio bursts using the properties of the supercritical shocks which can explain the brightness temperature, the frequency splitting, the bandwidth and the polarization of type II bursts.

In the case of supercritical shock waves 10% of the incoming ions are reflected in the upstream and in the downstream. These ions are unstable relative to the excitation of lower hybrid waves, whose phase velocities are anisotropic: $\omega/k_{\parallel} \gg \omega/k_{\perp}$. Such waves resonate with the background electrons and accelerate them to very high energies forming the superthermal tail in the electron distribution function. This distribution is stable for the excitation of Langmuir waves. Electrons are scattered by whistlers, excited by the reflected ions, and form a gap distribution in velocity space (at $> 43\ V_A$). These energetic electrons in front and behind the shock front give rise to high energy density of Langmuir waves which subsequently are converted into transverse waves forming fundamental radiation (in ordinary mode). The polarization percentage depends on the magnetic field in the source. Due to scattering by density inhomogeneities (resident in the source itself) depolarization results. The broad range in polarization measurements indirectly confirms this hypothesis. The continuum is more depolarized than the fine structures which are generated in smaller sizes. The electrons present in the upstream are responsible for the low frequency part in the band splitting whereas those in the downstream are responsible for the higher frequency part.

The harmonic band is due to the merging of two Langmuir waves, one generated by electron beams and the other is the secondary Langmuir wave getting backscattered by the ion sound waves. The mode should be extraordinary, however it depends upon the radiation mechanism invoked. The only second harmonic polarized example in our list is extraordinarily polarized.

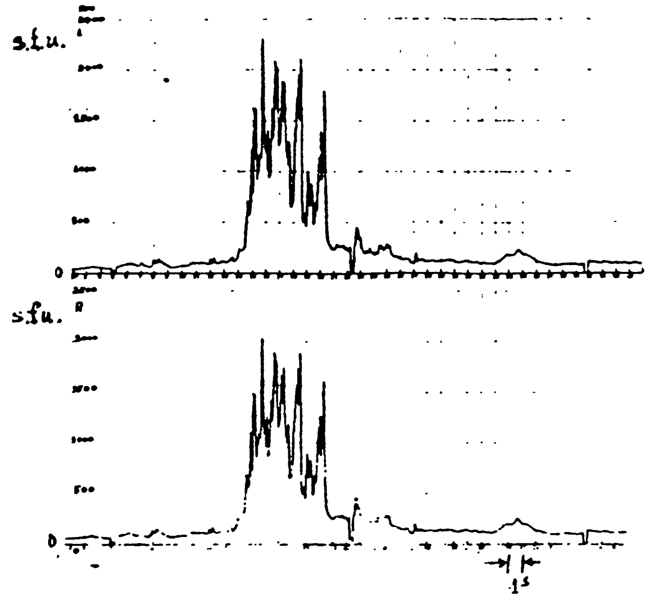

Fig.1. A typical example of "A" structure, observed on Feb. 8, 1982 at 327 MHz.

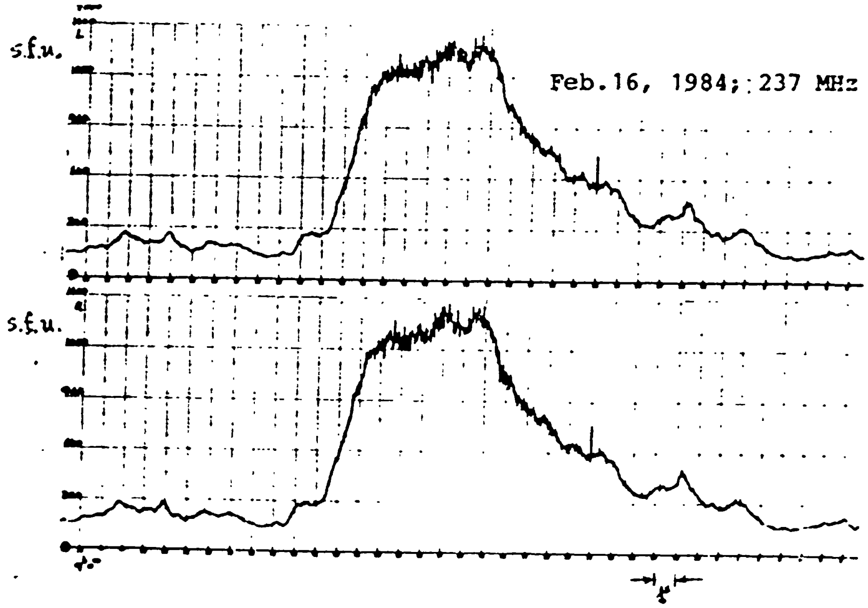

Fig.2. An example of structure "B".

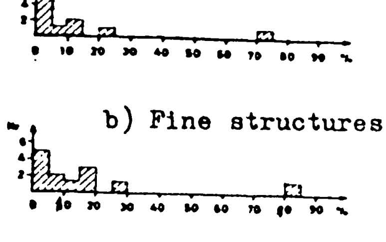

Fig.3. Histogram for different polarization percentages.

In particular the blobby nature of type II bursts may be due to the requirement that the favourable condition for their generation is the supercritical quasi-perpendicular character of the shock: whenever this condition is not satisfied the radiation is absent. Some electrons escape the upstream and downstream outrunning the already existing population and form fine structures ("A" type structures). When such fast electrons are not present "B" structures appear. The nature of these electron beams is different at distinct points showing different properties for distinct blobs. A more detailed paper will be published elsewhere.

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SVOJSTVA RADIO PROVALA TIPA II UZ OPAŽANJA VELIKOG VREMENSKOG RAZLUČIVANJA I KARAKTERISTIKE POLARIZACIJE

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saopćenje

SAŽETAK: Prikazuju se novi rezultati istraživanja Sunčevih provala radio zračenja tipa II temeljeni na opažanjima velikog vremenskog razlučivanja i analizi polarizacije. Fine strukture se uglavnom pojavljuju na početku nekog događaja i polarizacija im ostaje cijelo vrijeme konstantna, a do 15% su jače polarizirane od pozadinskog zračenja dok je smisao polarizacije isti. Katkada i kontinuum može biti snažno polariziran. Opažački podaci dobro se slažu s predloženom teorijom.