DIGITALLY RECORDED TYPE I BURSTS AND SOME THEORETICAL ASPECTS OF CONTINUUM AND BURST GENERATION

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ABSTRACT

In the first part we present the analysis of digitally recorded type-I bursts. The reduction procedure is described and some typical examples and results are presented.

In the second part we propose a model for type-I emission, compatible with low magnetic field strengths.

Incoherent langmuir waves, spontaneously emitted by trapped fast electrons are converted to transverse radiation by coalescence with low frequency whistlers. Recurrent upper hybrid instability in strong m.h.d. pulses explains the bursts in this model.

INTRODUCTION

The Dwingeloo 60 channel radio spectrograph measures the flux densities in both circular polarization modes. The sum (I_{tot}) and difference (I_{pol}) of these signals (with time constant $\tau \simeq .01$ sec) are recorded on film and can be sampled too by a digital recording system, up to 200 times per second. 20 Channels on the low frequency side have fixed central frequencies of 160 to 177 Mhz and individual bandwidth of .9 Mhz.

The other 40 channels have an individual bandwidth of .17 Mhz, together they occupy a selectable band of 13 Mhz in the range from 200 to 320 Mhz. The noise in the narrow channels with Quiet Sun observations is of the order of 1 Solar Unit (S.U.; 1 S.U. = 10^{-22} w/m^2 s Hz).

From September '75 until February '78 many of the observations have been made with special attention to solar noise storms. This paper presents a first analysis of some of the digitally recorded data in that period. We have restricted ourselves to the analysis of isolated single type-I bursts.

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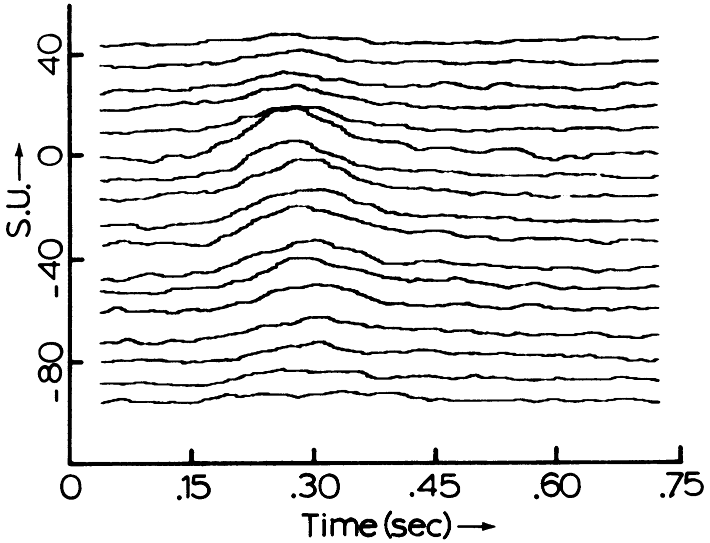

Figure 1. - Multichannel plot of a type I burst.

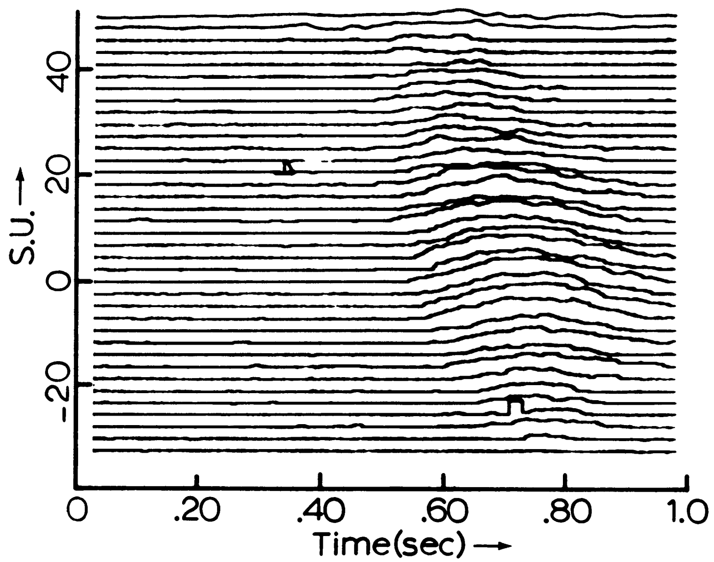

Figure 2. - Multichannel plot of a type I burst.

The Utrecht Radiogroup prepared procedures and computer programs to reduce the Dwingeloo spectrograph data in general and to analyse the bursts specifically.

PROCEDURE

Bursts are selected from film by the following criteria:

- the burst must look simple and last shorter than 1 sec.;
- the burst must be clearly isolated from other bursts.

A computer program selects a rectangular field of the time-frequency plane from tape and reduces the raw data to Solar Units using the relevant calibration data. For each channel a straight line is fitted to the background and the burst is detected as a more than 3 sigma deviation from this fit.

The background is subtracted and I_{tot} plotted in a multichannel plot, as in figures 1 and 2.

For the channel containing the peak of the burst we plot I_{pol} with I_{tot} for the upper half of the burst, so one can judge the

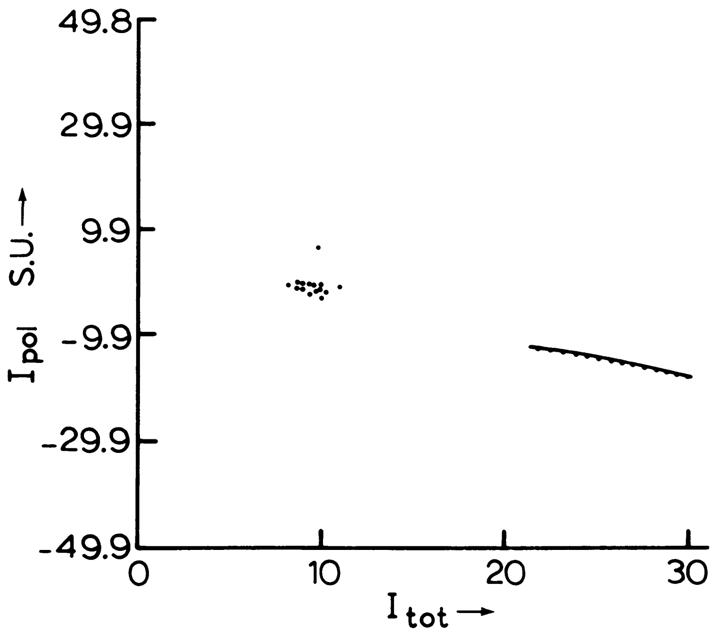

Figure 3. - Polarisation plot of a type I burst.

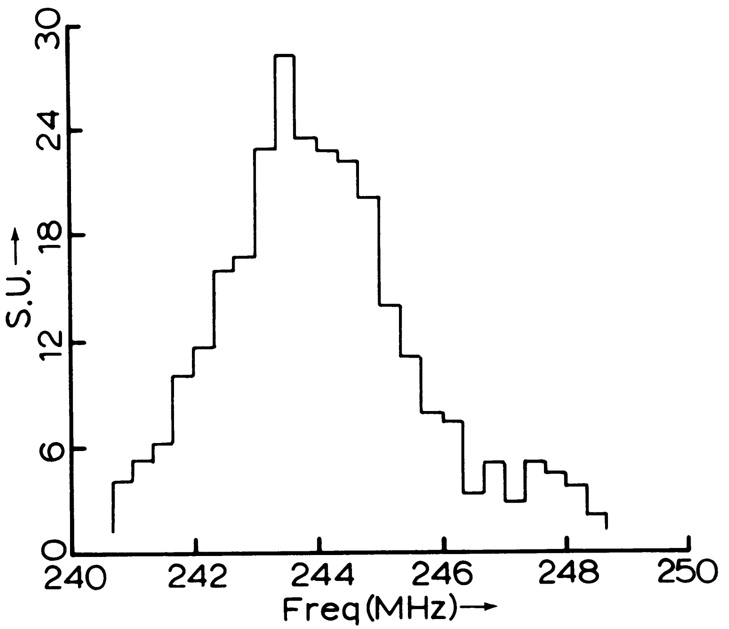

Figure 4. - Spectrum of a type I burst.

variation in polarisation degree (see fig. 3). The rising part of the burst is plotted as an unbroken line, the declining part as a broken line. The background noise is represented by unconnected dots.

The spectrum of the burst at the moment of the peak of the burst is plotted as in fig. 4.

The programs produce in addition to these plots several parameters describing shape, orientation, size, central frequency and polarisation of the burst. The exact choice of these parameters will be discussed elsewhere. 219 Bursts, observed on 11 different dates (2 of which relate possibly to the same noise storm) have been processed.

RESULTS

One variable to be observed in the multichannel plots is the noise in the background. The amplitude of this component varies from $\lesssim$ 1 S.U. to 3 S.U..

In the plots with low background noise one can observe that the burst has a noise component independent of the background noise (fig. 2). The amplitude of this component varies between $\lesssim$ 1 S.U. and 3 S.U. too.

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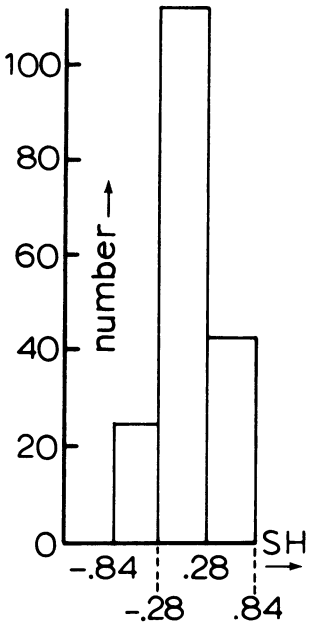

Figure 5. - Distribution of the skewness parameter of burst spectra.

The timescales in both these noise components are in the range from .05 sec. down to .01 sec. (the integration time of the instrument). There is no correlation of the noise in adjacent channels to be seen.

The polarisation of a burst is constant in time as evidenced by the traces in the polarisation plots (fig. 3). We want to emphasize that this conclusion is independent of possible errors in the background value.

To investigate the individual burst spectra we fitted gaussian curves to both low- and high-frequency parts of the profiles (calling the widths $B\ell$ and Bh respectively). The relative difference of the widths of the fits: $SH = Bh-B\ell \; / \; Bh+B\ell$ indicates the skewness of the profile. The distribution of SH shows (fig. 5) that most bursts have a symmetric spectrum.

Spectra with low frequency cutoff are found more often than those with high frequency cutoff in the minority of asymmetric profiles.

With the aid of regression analysis and scattergrams we have looked for correlations in the various parameters describing the bursts.

Apart from the well known variation of burst duration and bandwidth with frequency (Elgarøy '77) we found no new relations.

SOME THEORETICAL ASPECTS

The frequent occurrence and long persistence of type-I noise storms suggest the storms to be associated with common, non pathological conditions in the corona. Extrapolation from photospheric magnetic fields to the heights of type-I sources ($h \approx .4 \; R_\odot$) suggest field strengths in these sources of the order $\lesssim 5$ G (Dulk and McLean, 1978).

In the following we sketch a model for the Type I continuum emission and a related model for the (chains of) bursts, requiring low magnetic field strengths ($\omega_{ce}/\omega_{pe} << 1$) in contrast to some existing models, e.g. Fung and Yip (1966), Mangeney and Veltrie (1967).

CONTINUUM MODEL

Sakurai (1975) observed a storm continuum to start within a coronal mhd timescale after a change of the photospheric field type from smooth ($\beta\rho$) to irregular ($\beta\gamma$). Relaxation of the magnetic field near the top of magnetic arches, triggered by these changes in the photospheric field may be a source of trapped fast particles in the arches. Other sources for trapped suprathermal electrons may be considered. Collisions with the background will isotropize these electrons and coherent Langmuir waves will not be produced.

However, a gap distribution of non relativistic electrons will produce incoherent Langmuir waves with effective temperature $T_\ell \leqslant 6 \times 10^9$ K as shown by Robinson (1977). This value seems to be the observed upper limit for the brightness temperature T_t of the Type I continuum, so we need efficient conversion of Langmuir waves into electromagnetic waves.

Here the coupling of Langmuir waves with low frequency whistlers is proposed as a conversion mechanism. In low magnetic field strengths the abundance of whistlers can possibly be high enough for efficient conversion of this kind.

When

$$E_{\|} = \tfrac{1}{2}\, m v_{\|}^{2} \geqslant E_{cs} \approx \frac{B^2}{8\pi\, n_e}$$

electrons can participate in resonant whistler generation. For $B = 1$ G and $n_e = 5 \times 10^8$ cm^{-3} even thermal electrons satisfy this condition.

When T, K and ω denote effective temperature, wavenumber and frequency of the waves, with subscripts ℓ, t and w for Langmuir, transverse and whistler modes, we have: (Melrose, 1970)

$$T_t(k) \leqslant \frac{\omega_t\, T_\ell\,(k') \,.\, T_w\,(k'')}{\omega_w\, T_\ell\,(k') + \omega_\ell\, T_w\,(k'')}$$

since $\omega_t \approx \omega_\ell \approx \omega_{pe}$ it follows: $T_t \leqslant \min\left(T_\ell\,,\, \frac{\omega_{pe}}{\omega_w} T_w \right)$.

For $T_t \approx 6 \times 10^9$ K (the apparent upper limit) :

$$\frac{\omega_{pe}}{\omega_w} T_w > 6 \times 10^9 \text{ K}$$

with: $\omega_w \approx 0.1\, \omega_{ce} \approx 2 * 10^{-3}\, \omega_{pe}$

we get: $T_w \geqslant 10^7$ K.

Since this is only slightly suprathermal we expect sufficient whistlers with this effective temperature.

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BURST MODEL

In the context of this continuum model, the burst component can be explained by a recurrent upperhybrid instability occurring in strong $\left(\frac{\delta B}{B} \approx 1\right)$ mhd pulses in the continuum region. Anisotropic heating of the fast electrons in the pulse will enhance their loss cone to give rise to a double humped $v_\perp$ distribution of the electrons.

Now stimulated plasma wave emission at the upper hybrid frequency can take place (Kuijpers, 1975; Zheleznijakov et al., 1975) when $\omega_{UH} = n\omega_{ce}$ (with $\omega_{UH}^2 = \omega_{pe}^2 + \omega_{ce}^2$ and integer n) .

With $B = 2G$ and $\omega_{pe} \simeq 150$ Mhz , $n = 25$ e.g. can be a typical value for generation of (chains of) bursts in a travelling pulse.

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DISCUSSION

Vlahos: Can you say if we have information about the size of the continuum source? Is it roughly the same size as the large loop structure or is it much smaller?

Kattenberg: We have done some investigation on the continuum brightness temperature, using the Solar and Geophysical data and flux data obtained at Nera. We don't have data of our own on the size of the continuum sources.

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