OBSERVATION OF TYPE I CONTINUUM RADIATION ON JULY 9-13, 1978
AT DUERNTEN

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1. Introduction

Solar noise storms are the most common manifestation of coronal activity at radio wavelengths. This enhanced radiation is composed of a so-called type I continuum, lasting for several hours or days, and individual type I bursts of short duration (\(\lesssim 1\) s) and narrow bandwidth (\(\lesssim 10\) MHz). A detailed description of observations, correlations with other phenomena and theories can be found in Elgaroy (1977).

The purpose of the present study is the investigation of spectrum and polarization of the continuum emission from 200 to 600 MHz as a contribution to an international workshop on this topic.
2. Observing mode of the Dürnten Polari-Spectrometer

The Dürnten Polari-Spectrometer, IKARUS, is a swept spectrometer from 110 to 1000 MHz with computer controlled selection of frequency, switch code and mode of the digital data acquisition. The possible modes of operation are described by Perrenoud (1977). The bandwidth is fixed at 1 MHz, and the intensity scale is logarithmic. For the observation of the slowly varying continuum emission we used the instrument as an integrating Dicke radiometer. The effect of a Dicke radiometer with a logarithmic detector is not to cancel out variations of the receiver noise but to eliminate gain variations and DC-shifts completely.

An additional feature of this mode is an automatic disturbance limiter, which suppresses the integration of disturbed data. The disturbance limiter acts independently on each individual frequency. Data points are used for integration if their values do not exceed the running 32 s average by more than the disturbance limit. Disturbed data are being replaced by the mean value of the previous, undisturbed data. The limit was chosen as 12 digital units, corresponding to the 4 σ noise level of the unintegrated data. At low intensity levels this disturbance limit corresponds to 10 solar flux units, almost independent of frequency (above 200 MHz). This limiter not only suppresses the integration over short duration man-made
interference signals, but also diminishes the contribution of type I bursts to the integrated data. It is clear that a simple, automatic limiter cannot eliminate type I bursts completely. However we do not consider this disadvantage to be a serious problem, since the energy contained in bursts is much smaller than in the continuum (Elgaroy 1977).

The frequencies of observations are selected by the frequency program number 29 of the Radio Astronomy Group. The observed spectrum is the interval 120 - 630 MHz which is swept in 2 MHz steps in 1 ms time intervals. During the first 0.5 ms the right handed and during the following 0.5 ms the left handed circular polarization is being measured. The Dicke switching between antenna and load at room temperature is done in 100 μ s steps and 100 μ s are reserved for changing frequency or antenna. The data are integrated over 30 s periods which gives an effective Dicke integration time τ = 48 ms for each frequency and polarization. According to the radiometer formula

$$\frac{\Delta T}{T} = 2 \sqrt{\frac{B}{\tau}}$$

(Bandwidth B = 10^6 Hz, T = T_A + T_{syst}, T_{syst} ≈ 1000 K) we find a relative resolution ΔT/T = 0.009. For the 5 m dish, which we used for the observations, the antenna temperature T_A of the quiet sun is of the order of 1000 K for frequencies above 300 MHz and falls off strongly towards lower frequencies. The rms resolution relative to the signal from the quiet sun is therefore ΔT/T_A = ± 2% for frequencies above 300 MHz.

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This predicted resolution agrees well with the observations. The low sensitivity of the antenna below 200 MHz made it impossible to use the data for a quantitative analysis. In addition the significant contribution from galactic radiation made it difficult to find the correct value for the background radiation.

The background was determined every morning, shortly before sunrise at an elevation of 18°, not too far from the sun.

We had some additional problems with ground reflections which interfered coherently with the direct signal. The resulting ripple was about ± 20% during the morning hours of July 10, disappeared in the afternoon and was smaller on later days. We found that the ripple did not influence the observed polarization. An example of a spectrum with typical ripple is shown in Figure 1, a noise storm spectrum of July 12. On the logarithmic scale of this figure the ripple appears with the same phase and amplitude (in mm) for both polarizations. The appearance of the ripple on both polarizations helps to identify it for elimination in the figures to be shown.
3. Calibration of the instrument

The digitalized data are stored on magnetic tape. To convert the binary 16-bit-words to solar flux units, the tape is fed to a CDC-6400/6500 Computer and the data run through a calibration program. 3 levels of reference-data are used to calibrate in sfu.

First we have used the Dicke mode with a switching speed of 5 kHz. That means, we have taken the data as a difference measurement to $T_0$. With a logarithmic detector, this eliminates gain variations of the amplifiers and DC-shifts but not changes in the receiver noise.

Second, several times a day for every frequency integrated measurements of 3 well-known reference temperatures are taken and also written on tape. Out of those the computer can calculate amplification factor and receiver noise for every frequency. So we can convert our binary words to antenna temperature.

The third step is the calibration of the antenna. This has been done by comparing longtime-integration-measurements of the quiet sun on selected days with calibrated data from Sagamore Hill, Ondrejov, Torun, Hiraiso and Bordeaux radio observatories, interpolating the spectrum for the frequencies where we had no calibrated data and assuming the quiet sun to be unpolarized on August 22, 1978. Disturbances of the measurements were
thrown out by hand and the resulting set of data fed back to the computer. Now the computer can convert every binary word to solar flux units.

A comparison of calibrated data showed that our calibration overestimates the flux by about 20% at frequencies above 300 MHz, if the flux values are compared with a spectrum averaged over different observatories. A reason for this is the strongly overestimated 606 MHz flux of Sagamore Hill Observatory.
4. Results

During the period July 10 - 13 we observed two large noise storms both of which started within the decay phase of major flares in McMath plage 15403 and major type IV bursts. Both storms were highly polarized in the sense of left handed (according to Trieste, but contradicting to Nançay) circular polarization from 200 to 500 MHz. In addition to the two major storms there was already storm activity on July 8 and 9, and in between the two major storms a small storm with opposite sense of circular polarization was observed.

The first major storm appeared in the aftermath of the type IV burst of July 10. The spectra of Figure 2 show 3 steps of this process. The spectra show left and right circular polarization separately. The total intensity is the sum of $I_x$ and $I_\perp$.

The first spectrum (0550 UT) is the spectrum of the sun before the flare. The same spectrum was observed 24 hours before: a characteristic hump at around 260 MHz, slightly larger in the left circular polarization and a change of polarization at 500 MHz.

The second spectrum (0630 UT) shows the developed type IV burst. The transition from left to right polarization changed to a lower frequency. This spectrum must be interpreted with some caution because of the disturbance limiter which suppresses too fast intensity increases.
The third spectrum is taken during the decay phase of the type IV event (0744 UT). It already shows a characteristic exponential spectrum which seems to be characteristic for noise storms at high frequencies. Note that the spectrum of the total sun is shown always.

Without more type IV events except for a burst at about 0805 UT the noise storm developed gradually to a maximum at 1538 UT. This situation is shown in the spectra of Figure 3. It is worth noting that the spectrum of 1540 is indistinguishable from the spectrum of 1536 but a distinct change occurred at 1538 to a maximum at frequencies below 300 MHz with a peak frequency at 240 MHz. At this time however the intensity was lower at frequencies above 300 MHz than at 1536 and 1540. Note that the right circular polarization was close to the quiet sun value during the whole time. The changes in the right polarization were visible only below 300 MHz and may be due to cross polarization of the antenna. The degree of circular polarization of the noise storm was at least 95%.

The growth of the noise storm was not monotonic. Two examples of time variations are shown in Figures 4 - 7 showing the periods 1410 - 1600 UT and 1612 - 1728 UT at individual frequencies. As expected the changes are only in the left handed polarization with the exception of an event at 1652 UT.

Short and long time fluctuations are present constantly in the storm radiation. Figure 7 shows that the fluctuations are of broad band nature (>50 MHz). Some short time variations
of about 1 minute are not completely resolved in time. The noise storm started to decay after a type IV burst with start at 1730, and the next morning the left handed storm was gone as shown by the spectrum of Figure 8. Below 350 MHz the polarization was reversed and the intensity was at a similar level as on July 10 0550 UT. At higher frequencies there was unpolarized radiation at an enhanced level.

The next major type I storm evolved from a great type IV event with start on the same day (July 11) at 1050 UT. The storm was again left circularly polarized but did not grow to a maximum. It decayed slowly for about 2 days as shown in Figures 9, 10 and 11. Again broad band fluctuations were visible in this storm.

The high frequency tail of the radiation decayed more slowly than the lower frequency radiation, perhaps because of an increase of the s-component.

As a concluding remark we would like to mention that the high frequency part of the noise storm continuum forms an exponential spectrum. As an example, if we take the right handed emission as the background radiation then the left handed noise spectrum of July 10, 1558 UT decays exponentially from 100 sfu at 200 MHz to 11 sfu at 360 MHz.
The maximum frequency of the noise storm seems to lie below or close to 200 MHz. Only during the maximum phase we find peak frequencies at 260 MHz. According to earlier work (see Elgaroy 1977, p. 29) such high peak frequencies are outstanding.

References:


Comment on the Discussion

During the discussion of this contribution, the point was raised whether the fluctuations of 1978, July 10, 16, 14 - 1730 were due to a type I continuum or not. We have checked our analog recordings of that time and found weak type I burst activity in the range of 200 - 250 MHz, the lower limit of the observed band. Film recordings provided by H. Urbarz, Weissenau confirm this fact. In addition they show that the continuum in this interval had its spectral maximum around 80 MHz. Furthermore they indicate that the type I burst activity was very strong below 160 MHz with a maximum around 100 MHz. Also throughout this interval storm type III activity occurred below 50 MHz. The Weissenau spectrum is saturated around 1635 for 10 Minutes.

Although this does not directly prove that the observed fluctuations were part of a type I continuum, the typical storm activity before and after it is an indication for this association. Furthermore we note that both continuum and bursts have the same polarisation and a similar spectral distribution. This picture is confirmed by observations at 230 MHz in Trieste.
Fig. 1.

Fig. 2.

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Fig. 3

Fig. 4.
Fig. 8.

Fig. 9.

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Fig. 11.