Preliminary Results of the Zurich Radiospectrograph

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Abstract. The new broadband solar radiospectrograph at the Swiss Federal Observatory, Zurich, covers the frequency range 100—1000 MHz or any selected portion, in one continuous, linear sweep. The sweep recurrence rate may be varied from 0.2 to 20 Hz. Examples are shown of bursts of types III, IV and V recorded using the full frequency range and a 4 Hz sweep rate, under which conditions the instrumental threshold is of the order of 100 solar flux units. Complete digitalization, with higher sensitivity, is in progress.

1 Introduction

A new broadband solar radiospectrograph is nearing completion at the Swiss Federal Institute of Technology. The Zurich radiospectrograph is a joint project of the Swiss Federal Observatory, under the direction of Prof. M. Waldmeier, and the Microwave Laboratory, under the direction of Prof. G. Epprecht.

The new instrument is of the swept-frequency type with a variable sweep-recurrence rate, normally set at 4 Hz. The frequency range 100—1000 MHz, or any selected portion thereof, is covered in one continuous linear sweep. Only minor variations of receiver sensitivity exist in the entire frequency range. Gain variations due to antennae will be reduced in the final instrument. Preparations are being made for digitalization of the spectrograph output with an on-line computer, which will provide frequency and time profiles or spectral plots of iso-intensity contours with the full dynamic range of the receiver.

The use of one continuous, linear sweep overcomes the problems caused by the irregular frequency scales and large sensitivity variations of traditional broad-band spectrographs. The comparison of burst parameters at different frequencies is only reliable with uniform sensitivity, as is the study of the distribution of burst types and occurrence with frequency.

The ability to make frequency profiles with 1 MHz resolution, the system bandwidth, over such a large range is important in the study of continuum bursts. Dynamic spectra recorded on film have insufficient dynamic range. Dynamic spectra constructed from single-frequency registrations of several observatories suffer from timing and calibration differences and frequency separations comparable to the bandwidths of some decimetric continua.

The chosen frequency range provides observations of bursts characteristic of both metric and decimetric wavelengths. The frequency range also includes the discontinuity at ca. 600 MHz, between the centimetric and metric branches in plots of peak burst intensity versus frequency for large radio events. (Waldmeier, 1955; Fokker, 1969).

2 The Instrument

Two antennae, both sensitive to linear polarization are currently being used (Figure 1). A shallow 5 meter diameter dish (focal ratio = 0.80) with a log-periodic wedge feed constructed for 300—1000 MHz is coupled at the receiver to a log-periodic dipole antennae constructed for 80—1000 MHz. At 50 percent aperture efficiency the 5 meter dish would provide an effective area of $\approx 10\text{m}^2$. The aperture efficiency has not been measured; it may be ¡ 50 percent owing to the necessary defocusing of parts of the large broadband feed. The gain of the log-periodic dipole antenna is rated at ≈ 5 dB, but appears to be much higher in practice at the low frequency end of its range (see section 3). This discrepancy may be due to the illumination of the dish with the back lobe of the log-periodic dipole antenna, which is mounted back to back with the dish feed.

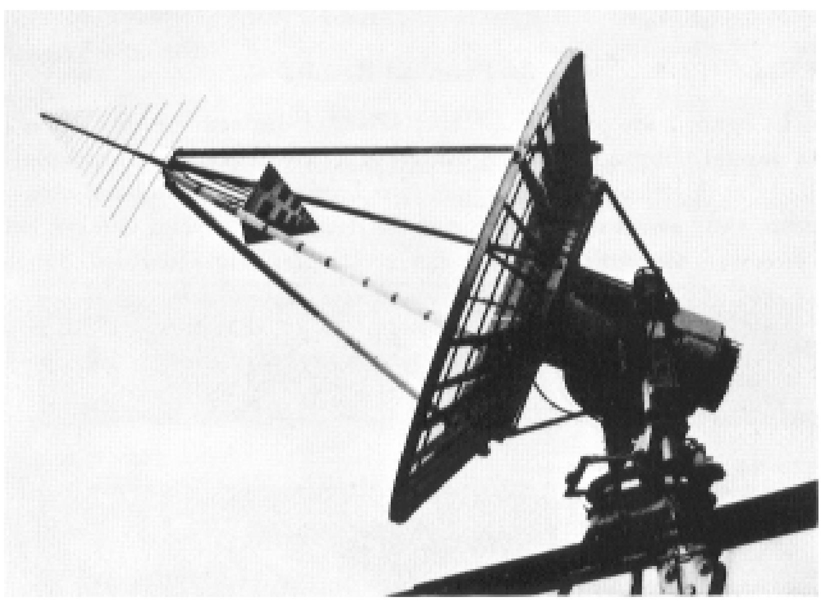

Fig. 1. Antenna system of the Zurich spectrograph.

The receiver (Meyer, et al., 1970; Asper, in preparation) is based on a parametric up- converter (Asper, 1971) . The problem of sweeping a 10 to 1 frequency range is solved by using a 10.3 GHz first stage intermediate frequency (i.f.) and sweeping the first stage local oscillator from 9.3 to 10.2 GHz, only a 10 percent change of frequency. Subsequent stages convert to 70 and 30 MHz before detection. The receiver has a dynamic range of $\approx$ 50 dB and provides a logarithmic output. Any frequency range within 9.3 to 10.2 GHz may be used for the first stage local oscillator. Hence, any portion of the range 100—1000 MHz may be chosen for observations. The sweep- recurrence rate may be varied from 0.2 to 20 Hz ; 4 Hz is normally used. Covering the full 900 MHz range in the 250 ms sweep period, the i.f. bandwidth is swept through ('sampled') for 0.28 ms. A time constant of 0.20 ms is normally used. Under these conditions, the receiver has a measured minimum detectable noise temperature fluctuation (i.e., noise temperature fluctuation = receiver noise) of 2000K. In the present system configuration, this detection threshold corresponds to an antenna temperature of $\approx$ 8000 K. Galactic contributions are $\ll$ 8000 K and thus affect neither the general noise level nor the detection threshold. The antenna receiver system thus has a practical burst detection threshold of $\approx$ 100 solar flux units (1 solar flux unit = $10^{-22}\mathrm{wm}^{-2}\mathrm{Hz}^{-1}$) for 300—1000 MHz. The threshold should be higher for 100—300 MHz, which, as will be shown in the next section, is not the case. The threshold for visual detection of bursts on the film recordings will necessarily be higher than the antenna-receiver burst detection threshold.

The sensitivity of the system will be increased in the future by reducing the noise figure of the receiver. Furthermore, while operating the on-line computer, the local oscillator frequency will be stepped (instead of swept) through 500 chosen frequency steps, thus both avoiding interference such as television carriers and increasing the sampling time of each frequency. The computer will also correct for fluctuations of sensitivity across the observing frequency range.

3 Practical Results

In Figure 2 are plotted peak flux values of distinctive events reported by several observatories from calibrated single-frequency measurements. Daily or three-hour average "quiet sun" levels are added to burst components. Only events occurring during the August, September, October, and November observing hours of the spectrograph are included. Bursts visually detectable on the film recordings at the frequencies in question are indicated by $\circ$, bursts not detectable by $\bullet$. When detection is uncertain (often due to interference), the symbol – is used. The overall system threshold is indicated approximately by the line. Performance will have varied over the four months used; the threshold is only approximate for a given day. The intensity level corresponding to film saturation has not yet been determined.

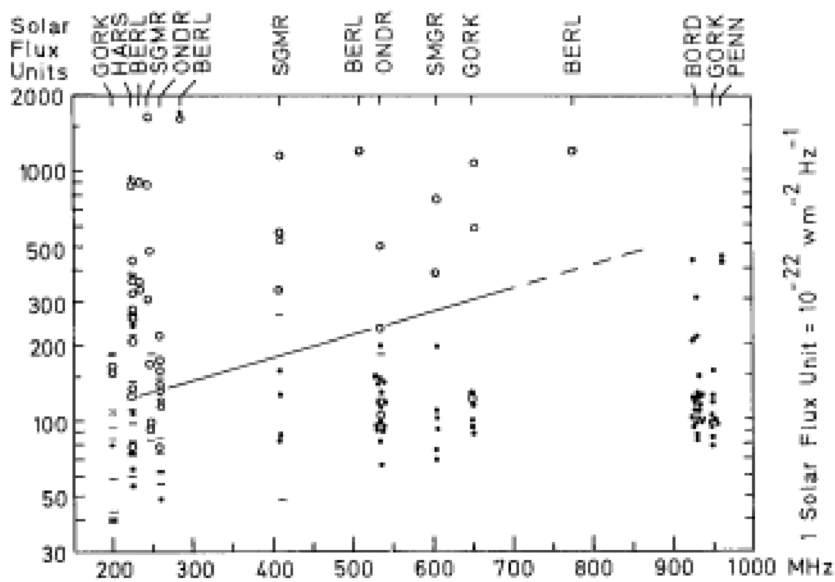

Fig. 2. Peak flux values of distinctive events which are (∘), or are not (•) , detectable in August through November film records of the spectrograph. The dash (−) designates uncertain events. Daily or 3-hour flux averages have been added to burst components. The Observatory name abbreviations of the IAU Quarterly Bulletin on Solar Activity are used as are the Quarterly Bulletin correction factors for the measurements made at 200 MHz in Gorki (x 0.5) and 540 MHz in Ondrejov (x 1.8). The line indicates the approximate practical burst detection threshold of the film records of the spectrograph.

4 Observations

Examples of observations recorded on film during the autumn of 1972 are shown in Figures 3 and 4. For instrumental reasons, the low frequency edge of the film recordings varies near 150 MHz. Figure 3a. shows a complete film record; the other examples in Figure 3 are details from film records. The brief narrowband continuum burst in Figure 3a occurred while a noise storm was in progress and shortly after a flare of importance SB.

The horizontal structure is due to gain variations; the broadband variations in time are believed to be real.

The U-bursts of Figures 3b and c occurred during the passage of the Zurich region no. 1594/5 (Waldmeier, 1973), a period in which several U-bursts and type V bursts (see Figure 4) were recorded. Records from this period are being studied in an attempt to obtain information on the magnetic field configuration over this active region. The type III bursts in Figure 3d may be harmonically related. The frequency drift rates of the first and second bursts are, respectively, -70 ± 10 and -115 ± 15 MHz/s, which contain both the ratios 1:2 and 2:3. As

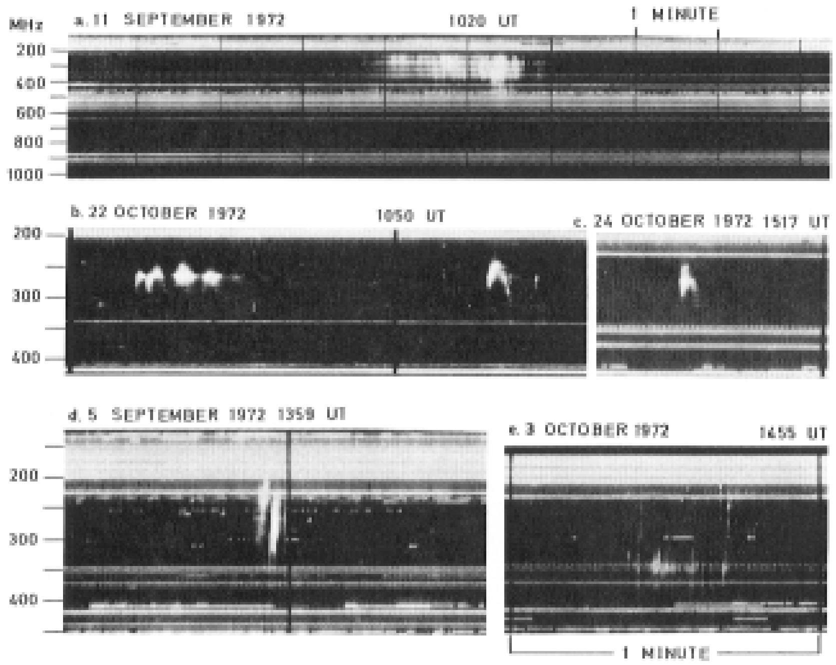

Fig. 3. Examples of spectrograph film records (see text).

the first burst is disappearing at about 200 MHz, the second burst starts near 400 MHz.

Figure 3e. shows a group of faint short-duration type III bursts with duration comparable to the 0.25 second sweep period. Two bursts extend from about 350 MHz to 220 MHz or less, with drift rates of ≈ -130 MHz/s. The second of these two bursts may have an harmonic companion starting at 230 MHz just before the burst becomes visible at 370 MHz. An extrapolation of the 370—200 MHz burst implies a frequency of ≈ 450 MHz at the starting time of the companion.

The intense type III burst group recorded by the spectrograph 1136 UT 25 October 1972 is compared in Figure 4 with the corresponding observations of the Weissenau Observatory of the Astronomical Institute of the University of T"ubingen (courtesy H. Scheerer). The event occurred during the maximum of an importance 1N flare in the Zurich region 1594/5. The most prominent feature of the Zurich record is a type V burst in which harmonic structure has been pointed out by Benz (1973). The lower threshold of the Weissenau instrument is responsible for the difference of appearance of the bursts at frequencies $<$ 300 MHz. The small scale structure ($\approx$ 1s $\times$ 3 MHz) in the Zurich record is instrumental.

A major departure from the format of traditional broadband spectrographs is apparent in Figure 4. Dividing the scale evenly (or approximately) into octaves is a better representation of the height-frequency relationship of bursts due to plasma oscillations and maintains an approximately uniform ratio $\Delta\nu/\nu$ across the observing range. However, the linear frequency scale facilitates the measurement of burst parameters and the detection of harmonic structure and provides a larger display of structure in decimetric bursts.

5 Research Programs

Observations will be reported routinely to the Quarterly Bulletin on Solar Activity. Furthermore, research programs are being planned for both continuum bursts and bursts due to plasma oscillations.

The large frequency range, ≈ 1 MHz bandwidth, and final uniform sensitivity and large dynamic range of the instrument will be particularly well adapted to the study of type IV dm bursts. The existing net of calibrated single-frequency observations is barely adequate to produce overall frequency profiles of narrow type IV dm bursts, while the structure often observed in such bursts can only confuse the recorded time profiles.

Frequency profiles with a higher density of observing frequencies are desirable for comparison with burst models.

The spectral jump in several events at ca. 600 MHz may represent the maximum frequency at which emission due to plasma oscillations may be observed in a particular burst. This high frequency cut-off may involve either the generation, propagation, and conversion of plasma waves or it may involve strong absorption of em-waves in the lower corona, an effect which would be important in interpreting all bursts observed above the jump. Malville (1967) has reported an apparent tendency of the average starting (maximum) frequency of type III bursts to increase with the general level of solar activity. The frequency range and uniform sensitivity of the spectrograph will be favourable for studying the variation of starting frequencies of both type III and type II bursts during the rising portions of the next solar maximum.

For several years to come there should be little ambiguity in identification of the center of activity responsible for a given burst. Spectrograph observations may be combined with optical solar observations obtained by the Swiss Federal Observatory to examine such subjects as association with optical activity and variation of burst parameters with position, type, or age of sunspot group.

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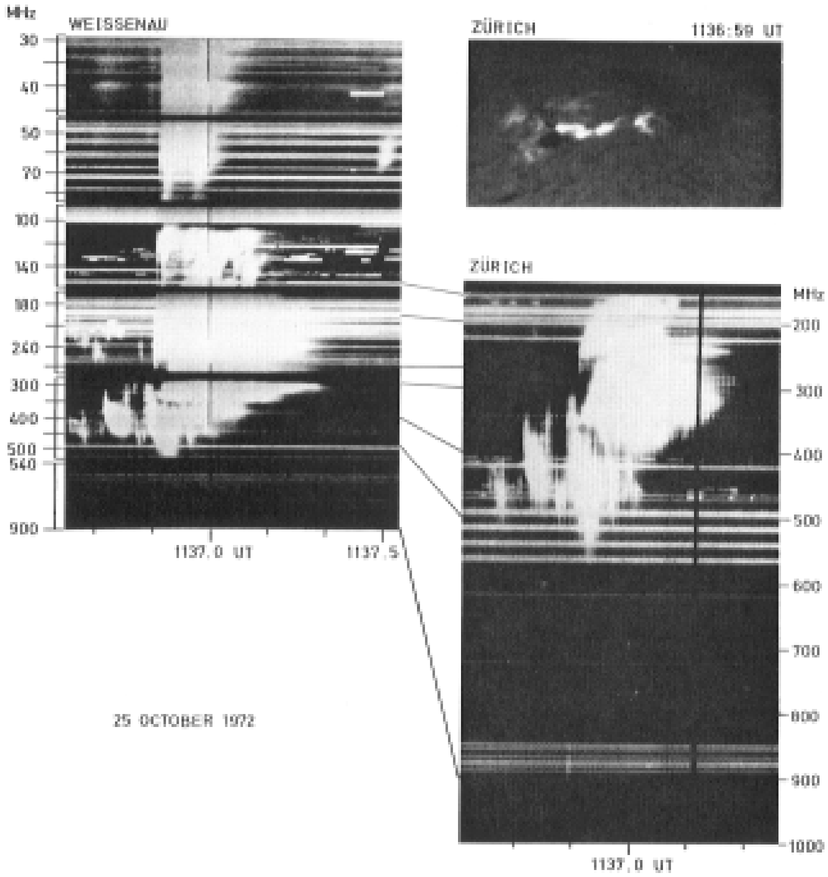

Fig. 4. Dynamic spectra of the 1136 UT 25 October 1972 type III-V burst event recorded with the Weissenau and Zurich spectrographs and the associated importance IN flare recorded by the Zurich Flare Patrol.

References

ASPER, H., Thesis, Swiss federal Institute of Technology, Zurich, 1971.

BENZ, A. O., Nature, 242, 38, 1973.

FOKKER, A. ID., Solar Physics 8, 376, 1969.

MALVILLE, J. M., Solar Physics 2, 484, 1967.

MEYER O., H. K. ASPER, P. HERRMANN and K. HILTY, Verb. Schweizer. Natf. Ges. 1970, S. 133.

WALDMEIER, M., Ergebnisse und Probleme der Sonnenforschung, second Edition, Akademische V erlagsgesellschaft, Geest and Portig K.-G., Leipzig , 1955, p. 334.

W ALDMEIER, M., Publ. Eidgen. Sternwarte Zurich, Vol. XIV, No. 2, 1973.

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