OBSERVATIONS OF SOLAR BURSTS OF TYPES II AND III AT KILOMETRIC WAVELENGTHS FROM VOYAGER

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The Planetary Radio Astronomy receivers aboard the Voyager spacecraft have been recording solar bursts of Types II (Boischot et al. 1980) and III (Riddle 1979) since launch in August and September 1977. The receivers themselves have been described in detail elsewhere (Lang and Peltzer 1977, Warwick et al. 1977). This study restricts itself to data from the 69 channels uniformly spaced between 20.4 and 1326.0 kHz. Each of these channels can be sampled once each six seconds, and the signal to noise ratio on each sample is about 0.8 dB. The sense of circular polarization to which a receiver responds alternates with each sample.

The ten or so individual Type II bursts observed on the Voyagers have appeared between the frequencies of 1326 kHz to 116 kHz. However, as described by Boischot et al. (1980), the individual bursts cover a lesser frequency range. The "typical" burst lasts about an hour and is often fragmented in both the time and frequency domains. Frequently there is emission at two frequencies at the same time (splitting). In one case two emission bands are harmonically related suggesting the observation of a fundamental harmonic pair (at about 30 $R_\odot$. Using the observed rate of frequency drift and assuming the density model deduced from RAE observations (Fainberg and Stone 1976) and fundamental emission we derive velocities (Table 1) higher than those normally observed for Type II events at higher frequencies. Different portions of the same event often give velocities differing by a factor of two. However in those cases where we can deduce a starting time for the Type II event at the Sun, the inferred average velocity is much closer to that inferred at higher frequencies.

The frequency splitting allows an estimate of local magnetic field strength if we follow the example of Smerd

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et al. (1975) and assume that the two frequencies are indicative of the plasma frequency ahead of and behind the shock. At 18 $R_\odot$ we derive values for B between 15 and 40×10^{-3} Gauss. These values are high compared to the currently estimated value of 7×10^{-3} Gauss (Dulk and McLean 1978) but would be lower if the average velocities were used. The discrepancy is not large considering the uncertainty as to the validity of the density model used. The general agreement of the derived magnetic field with the expected value leads us to believe that useful estimates of the magnetic field out to 30 $R_\odot$ could be obtained if Type II bursts were observed from a spacecraft receiver with suitable direction-finding capability.

Table 1. Derived Parameters for Type II Bursts

Date	Freq. kHz	Vel. km/s	Shock Mach #	B at 18 $R_\odot$ 10^{-3} Gauss	Avg. Vel. km/sec
78/4/2	800-400	780	2.04	15	
78/4/8	300-110	3000			1100
78/4/17	1300-500	3000	2.00	30	700
	500-320	2300			
78/4/19	800-690	2800			1300
	690-660	700			
78/4/28	1100-600	1600	1.40	40	1100

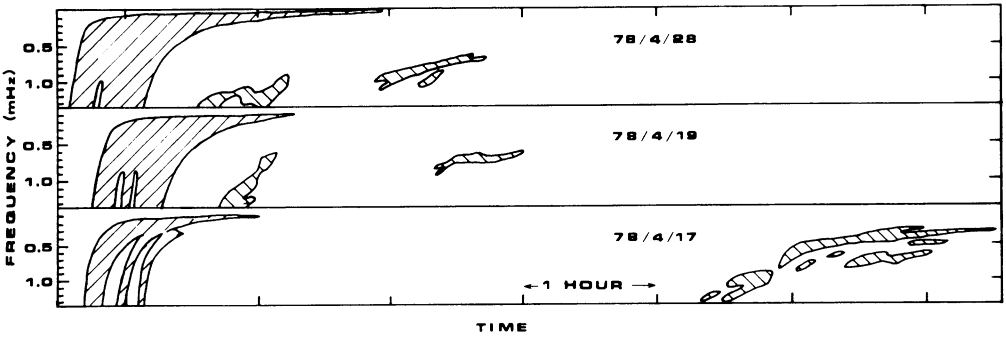

Figure 1. Spectra of Three Type II Bursts

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Only a few of the thousand of so Type III bursts observed from the Voyagers have been analyzed in detail (Riddle 1979). No evidence of circular polarization exists. A systematic excess of one sense of circular polarization over the other would be detectable at the 1 dB level (0.1 dB for ten events studied at frequencies of 190-310 kHz). This observation contrasts with the case at higher frequencies (~100 MHz) where polarization, especially at the leading edge, is not infrequent.

The time profile of the bursts in the 190-310 kHz range shows no structure on timescales below 6 sec (with 30 msec resolution) and at all frequencies appears to be described quite well by an analytic form $A(\alpha+\beta)\ (e^{-\tau/\alpha}+e^{\tau/\beta})^{-1}$ where α and β are the e-folding rise and fall times and τ is the time from peak intensity. This form fits simple bursts to within an rms error of 2σ where σ is the rms noise expected on a single measurement and data is taken at some small multiple of six seconds. As noted by Alvarez and Haddock (1973) the decay time β at frequency f fits quite well the relationship $f\beta=10^8$ derived by Wild (1950) for observations at meter wavelengths.

No evidence has been found in this data set of two classes of events such as might be expected if some Type III's were fundamental and some harmonic. Certainly no fundamental harmonic pairs have been observed, nor have any bursts which suggest a transition from fundamental to harmonic or vice-versa. The rise and fall times, as well as the exciter velocity (deduced from the RAE density model) do show at least a 2:1 spread in values but there is no evidence (in an admittedly small sample) of clustering into two groups as might indicate the presence of two distinct types of burst.

The spectral character of the bursts in this frequency range show considerable variation, as previously observed by Weber (1978). Peak intensities observed range from frequencies above 1.3 MHz down to 97 kHz. The bursts within a complex group often show different spectral characteristics. On the other hand some groups show bursts with almost identical spectra. Sometimes bursts occurring hours apart seem to be similar, suggesting some degree of homogeneity.

Having no direction-finding capability the Voyager observations do not lend themselves to discussions of deceleration of the electron streams generating the Type III bursts. However, for one burst on November 22, we do have additional information that is of great assistance. For that burst there were observations of electron density at 0.6, 1.0 and 1.5 AU (Helios, Imp and Voyager respectively)

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which suggest that the RAE density model was appropriate. Also, the location of the burst at 0.6 AU was determined and the solar wind velocity was known (~400 km/sec). The Nov 22 burst was strong down to 20 kHz which, assuming harmonic emission and the RAE density scale, means that it was observed out to 2.2 AU. The time of occurrence of the peak of emission at each frequency is consistent with a disturbance moving out along the appropriate Archimedes spiral with a constant velocity of 0.15 times the velocity of light.

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DISCUSSION

Stone: What was your lowest frequency of type III bursts observed? (Directed to Gurnett): What was the largest distance from the sun that you observed plasma oscillations?

Gurnett: About 1.5 AU.

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Riddle: We see quite a number of bursts on our lowest frequency of 20.4 kHz.

Stewart: Surely the instantaneous band width and duration of type III bursts at 1 MHz would be too large for you to be able to separate fundamental and second harmonic components?

Riddle: Certainly at lower frequencies we would expect that fundamental and harmonic would be impossible to separate due to lengthening time-scales, but at 1 MHz and higher there should be no problem. However, as yet, we have not noticed any such pairs.

Dulk: You have measurements of type III's from 40 kHz down to 1 kHz. Have you seen any polarization of that radiation which would be indicative of fundamentals or harmonics? And thus follow a fundamental to its end?

Riddle: At 40 kHz we have a real problem. The whole 40 kHz to 1.3 kHz range we have only sampled every 6 seconds at each frequency point in that range. Now if you could imagine 40 MHz, if you took a sample every 6 seconds you could be on the next type III or the next type III or the next type III. Also in the range 1.3 to 40 kHz we have spacecraft interferences much more than we anticipated and it's very hard to get good measurements all the way down and I've tried and I haven't succeeded. If anybody has a lot of time we have a lot of data.

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