# POLARIZATION AND POSITION MEASUREMENTS OF TYPE III BURSTS

S. Suzuki, G.A. Dulk† and K.V. Sheridan
Division of Radiophysics, CSIRO, Sydney, Australia
†Also Department of Astro-Geophysics, University of Colorado, Boulder, U.S.A.

## ABSTRACT

We report on the positional and polarization characteristics of Type III bursts in the range 24-220 MHz as measured by the Culgoora radioheliograph, spectrograph and spectropolarimeter. Our study includes 997 bursts which are of two classes: fundamental-harmonic (F-H) pairs and "structureless" bursts with no visible F-H structure. In a paper published elsewhere (Dulk and Suzuki, 1979) we give a detailed description and include observations of source sizes, heights and brightness temperatures. Here we concentrate on the polarization of the bursts and the variation of polarization from centre to limb. The observed centre-to-limb decrease in polarization approximately follows a cosine law. This decrease is not as predicted by simple theory but is consistent with other observations which imply that open field lines from an active region diverge strongly. The observed o-mode polarization of harmonic radiation implies that the wave vectors of Langmuir waves are always parallel, within about 20°, to the magnetic field, while the constancy of H polarization with frequency implies that the ratio $f_B/f_p$, the Alfvén speed $v_A$ and the plasma beta are constant with height on the open field lines above an active region. Finally, we infer that some factor, in addition to the magnetic field strength, controls the polarization of F radiation.

## 1. INTRODUCTION

Type III bursts are commonly thought of as being "unpolarized bursts", an appellation used by Payne-Scott (1949). This reputation persists despite many observations of varying degrees of circular polarization, usually ~0.1 but occasionally as high as 0.5. In the most extensive study to date, Suzuki and Sheridan (1977) (hereafter SS77) found that F-H pairs are usually polarized, the degree of polarization of the F component averaging 0.3 and that of the H component 0.13. The polarization was found to be in the same sense for both components and the degree of polarization to be nearly independent of frequency in the range 24 to 220 MHz.



*M.R. Kundu and T.E. Gergely (eds.), Radio Physics of the Sun, 315-322.*

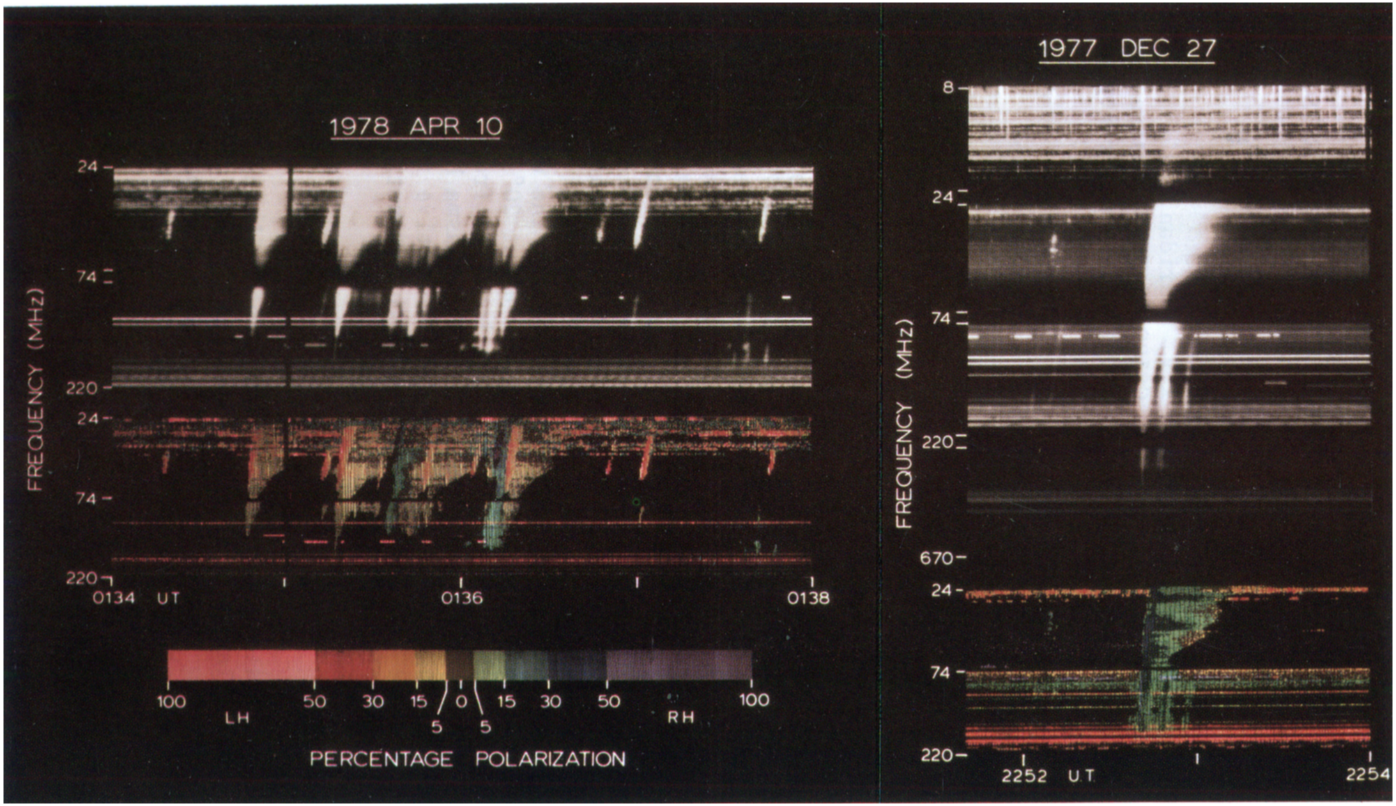


Fig. 1 - Spectrograph (black and white) and spectropolarimeter (colour) recordings of two Type III burst groups.

https://doi.org/10.1017/S0074180900037049 Published online by Cambridge University Press

Here (and in Dulk and Suzuki, 1979) we extend the study of SS77 with improved polarization discrimination, utilizing heliograph data on burst positions, and including a group of "structureless" bursts for comparison with the F-H pairs. We have selected only distinct, nearly isolated bursts whose polarization, if any, could be readily measured and which were apparently travelling on open field lines (as evidenced by their rapid drift rate and constant polarization that persisted to 24 MHz, the lowest observing frequency of the spectropolarimeter). We thus rejected all Type U bursts, peculiar IIIs, complex or overlapping groups, and storm IIIs. Altogether the 997 bursts chosen were about 10% of the total number of all types of Type III bursts occurring in the year of our study, June 1977 to June 1978.

## 2. OBSERVATIONAL RESULTS

Figure 1 shows two sections of polarimeter and spectrograph records containing F-H pairs. The F components stand out clearly - on the spectrograph because of their higher intensities and faster drift rates and on the polarimeter because of their more vivid colours, signifying higher polarization. Figure 1(a) contains both left-hand (LH) and right-hand (RH) polarized bursts which came from widely separated locations on the Sun. Figure 1(b) contains a RH burst with the F component extending to ~200 MHz, a rare occurrence. Usually F components are confined to <100 MHz; in fact, only 24% in our study extended to frequencies >80 MHz and less than 1% to >160 MHz. Thus F components are usually confined to a range from a few to ~100 MHz and are seldom or never seen at $\lesssim 1$ MHz (Fainberg and Stone, 1974) or $\gtrsim 200$ MHz.

Figure 2(a) shows the distribution of polarization for the 714 F-H pairs and 283 structureless bursts in our study. The F components have a wide distribution with an average $\langle p_F \rangle = 0.35$, the H components a narrow distribution with $\langle p_H \rangle = 0.11$ and the structureless bursts a concentration near zero with $\langle p_0 \rangle = 0.06$. For all F-H pairs we found: (i) the same sense of polarization for the F and H components; (ii) the degree of polarization nearly independent of frequency; and (iii) $p_F \geqslant p_H$ (but large variations in $p_F/p_H$ occur for different bursts).

Figure 2(b) shows the distribution of burst positions from centre ($\phi = 0°$) to limb ($\phi = 90°$) derived from position measurements at 80 MHz. Here $\phi$ is the great circle angle between the source and the centre of the solar disk on a sphere of radius $\rho_{80}$; we used $\rho_{80} = 1.6\ R_\odot$, the average observed radial distance of the bursts at 80 MHz. Then $\phi = \sin^{-1}(\rho/\rho_{80})$, where $\rho$ is the projected distance of the source from Sun centre. For bursts observed at $\rho \gtrsim \rho_{80}$ an adjustment was made so that the corresponding values of $\phi$ were randomly distributed between about 80° and 100°. The F-H pairs are concentrated near the disk centre, mostly at $\phi \lesssim 60°$. This is a new result, one predicted by Wild et al. (1959) but not confirmed by their limited data.

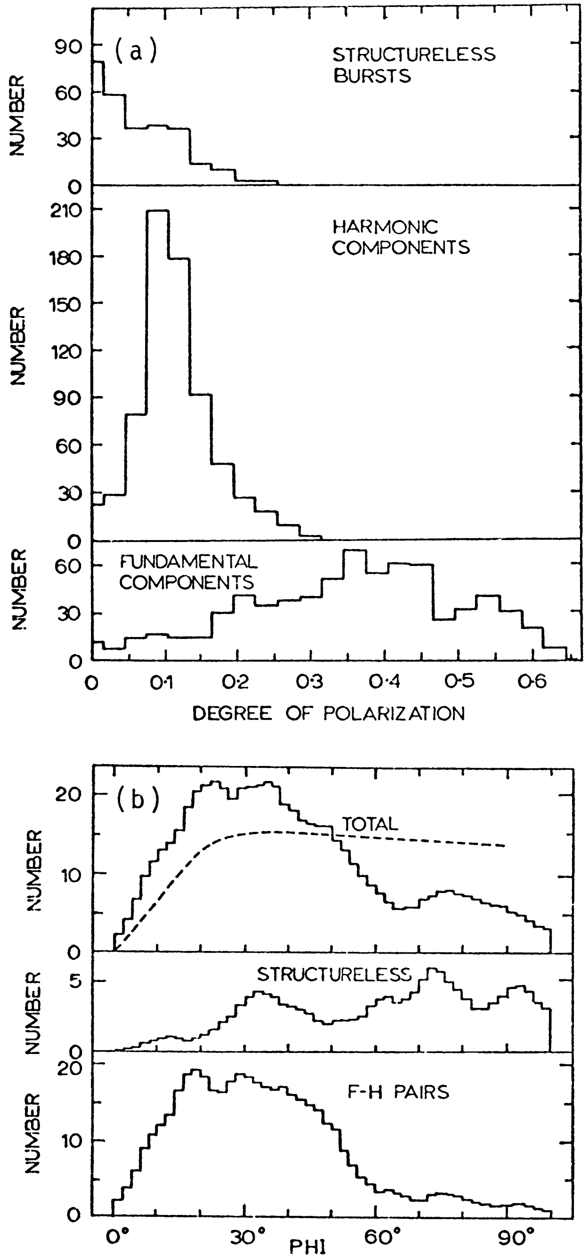


Fig. 2 - (a) Distribution of absolute values of degree of polarization for F components, H components and structureless bursts.
(b) Centre-to-limb distribution of F-H pairs, structureless bursts, and all bursts combined, derived from position measurements at 80 MHz. The dashed line gives the expected distribution if the bursts were uniformly distributed in longitude but confined in latitude in the manner observed. (After Dulk and Suzuki (1979), Figures 3 and 8.)

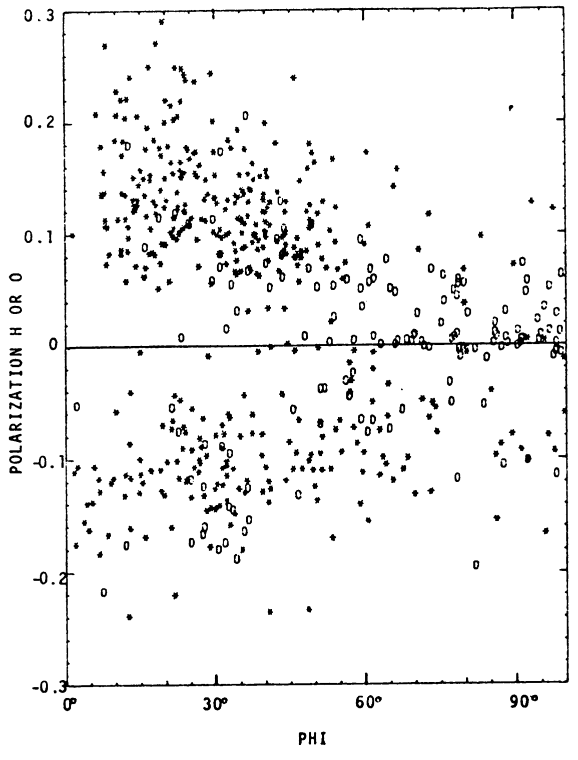


Fig. 3 - Centre-to-limb distribution of the polarization of H components (asterisk) and structureless bursts (zero) based on position measurements at 80 MHz. (After Dulk and Suzuki (1979), Figure 9a.)

Figure 3 shows the centre-to-limb distribution of burst polarization, the asterisk denoting H components and the zero structureless bursts. Two important results are evident: (i) the polarization of H components decreases from centre to limb; (ii) the structureless bursts are partly intermingled with the harmonics and are partly a continuation of the harmonic distribution to the limb. From the latter we infer that the structureless bursts are H components; the F radiation, possibly because it is more highly directive, is missing from most bursts near the limb and from a few near the disk centre.

## 3. INTERPRETATION

From a number of arguments, summarized by Dulk and Suzuki (1979), it is generally accepted that Type III radiation is o-mode. From the theory of H polarization developed by Melrose and Sy (1972) and

Melrose et al. (1978), it is found that the conditions for o-mode radiation are quite severely restricted; only if the Langmuir wave vectors are concentrated within about 20° of the field direction is the resulting emission in the o-mode. Therefore the evidence presented here and by SS77 implies that the Langmuir waves are so confined.

The observed centre-to-limb decrease in polarization is, on the average, approximately proportional to cos $\phi$. This decrease is not what is predicted by the theory when small, homogeneous sources and quasi-radial magnetic field lines are assumed. For such sources the polarization is predicted to rise slowly for $0° \leqslant \phi \leqslant 60°$, then more rapidly to a peak at $\phi \approx 85°$, and to drop to zero at $\phi = 90°$. However, as discussed in detail by Dulk et al. (1979), theory and observations can be reconciled simply by invoking large sources in which there is a rapid divergence of magnetic field lines. By representing (approximately) the sources as cones whose apexes are in the electron acceleration region, the decrease in polarization arises naturally if the opening angle of the cones is $\Delta\phi \gtrsim 60°$. It is easy to see that if such a large conical source were located near the limb, some field lines would have a component away from the observer and others a component towards the observer; therefore the resulting radiation would contain both senses of polarization and the net polarization would be near zero. (It should be remarked that the postulated large conical sources are consistent with observations of source sizes at various heights and with observations of interplanetary electron bursts at 1 AU (Lin, 1974); furthermore, when combined with the ideas of wave-ducting which were put forward by Bougeret and Steinberg (1977) and Duncan (1979), they also explain certain anomalies in F-H source positions.)

From the theory of H radiation and our observational result that the polarization is nearly always independent of frequency, we can infer that the ratio of gyromagnetic to plasma frequency $f_B/f_p$ (as well as the Alfvén speed and the plasma beta) is nearly always independent of height on the open field lines above active regions. The average values derived from the observations are $\langle f_B/f_p \rangle = 0.22$, $\langle v_A \rangle = 1400$ km s$^{-1}$, $\beta = 0.02$, and, at the 100 MHz plasma level for example, $B \approx 8$ G. These values seem to be rather high, but at present they cannot be challenged by any other theory or type of observation.

## 4. CONCLUSIONS

This study has helped to clarify some aspects of Type III bursts, such as the frequency range of the F component, the identification of structureless bursts as harmonics, the relationship between burst position and polarization, and the effects of large source sizes. However, the study has also uncovered new problems, such as the unexplained low and variable (from one burst to another) polarization of F components, the unexpectedly high values of $f_p/f_B$, $v_A$ and B implied by the observations and theory, and the requirement for electrons to be

https://doi.org/10.1017/S0074180900037049 Published online by Cambridge University Press

accelerated on to the many field lines which diverge to fill a very large volume of space.

*Acknowledgements.* We are indebted to the late Dr. S.F. Smerd for many years of arguments and discussions, during which he imparted to us some small part of his deep understanding of solar radiophysics.

We thank Mrs. J. Tuxford and Miss J. Thompson for their able assistance with the data analysis. Part of this work was supported by NASA under grant NSG-7287 to the University of Colorado.

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## DISCUSSION

Wentzel: I suggest a possible explanation for observed polarization of the fundamental emission. For various reasons, the electric fields due to electron beams are likely to be bunched. In effect, each bunch constitutes an antenna (cf. Papadopoulos and Freund, Geophys. Res. Letters 5, 881, 1978). Near the harmonic, the wavelength at a given frequency is longer for the extraordinary than for the ordinary mode. Thus the antenna is more efficient for the o-mode and one obtains net o-mode polarization. With some approximations (cf. Wentzel, Astronomy and Astrophysics, 1979 in press), $p = 1/2\ \Omega \cos\theta/(\omega_t - \omega_p)$, where the frequencies are electron cyclotron, radio and plasma frequencies, and $\theta$ is the angle between the radio emission and $\underline{B}$. The choice $\omega_t - \omega_p = 0.1\ \omega_p$ yields a reasonable magnitude of p, and the factor $\cos\theta$ is at least closely related to the observed cosine dependence on center-limb distance. This explanation yields very small polarization for the harmonic.

Sheridan: Apart from the mechanism of generation of the fundamental component of the radiation, the theory would have to account for the observed wide spread of the ratio of $(P_F/P_H)$ from event to event.

Kayser: Is the cone of diverging $\vec{B}$ lines filled with electrons, or is it a rim effect?

Sheridan: We have no ready explanation for how the electrons can fill such a large cone of diverging field lines. It would appear that the electron clouds must be injected on to field lines which thread the cone and this would place magnetic structural constraints on the region responsible for the electron acceleration.

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