THE POLARIZATION OF "HERRING-BONE" FEATURES IN SOLAR RADIO BURSTS OF SPECTRAL TYPE II

By R. T. STEWART*

[*Manuscript received January* 28, 1966]

Summary

The degree and phase of polarization of short-lived features in solar radio emission of spectral type II is investigated. It is found that although the type II burst is in general weakly or negligibly polarized it may contain highly polarized elements. In particular, the fast-frequency drifting features that appear to diverge from a type II burst ("herring-bone" features) are at times found to exhibit strong circular polarization.

I. INTRODUCTION

The solar radio burst of spectral type II (Wild 1950) is a comparatively rare metre-wavelength event lasting typically for 10 min and characterized by a slow systematic drift from high to low frequencies at rates of up to 1 Mc/s per sec. Its features are often sharp and of narrow bandwidth (often only a few Mc/s) and duplicated at the second harmonic frequency (Wild, Murray, and Rowe 1954). Sometimes type II bursts contain short-lived features. In particular, Roberts (1959) has reported the existence of bursts containing a rapid succession of short-lived broad-band elements, which have fast frequency drifts of both positive and negative signs and appear to diverge from a narrow-band feature that drifts from high to low frequencies at a rate typical of a type II burst. The resulting appearance is that of a "herring-bone". In the later stages of these bursts the rapidly drifting elements extend over a much smaller range of frequencies, and at times the central narrow-band feature or "core" is completely missing. An example of herring-bone structure in a type II burst is given in Plate 1. Here the rapidly drifting features extending to the lower frequencies are more developed than those extending to the higher frequencies. The herring-bone structure is seen in the fundamental and to a lesser extent in the harmonic features of the burst during the early stages. Later in the event the herring-bone structure disappears completely leaving a typical type II burst.

The polarization of type II bursts has been studied over a wide frequency range (40 to 240 Mc/s) by Komesaroff (1958) and found to be very weak, if present at all. A recent study by Rao (1965) has shown that type III bursts of very short durations (1–2 sec at 40 Mc/s) are often highly circularly polarized (up to 70%). Since these bursts show a remarkable spectral resemblance to the fast drifting elements in the herring-bone structure of type II bursts, it was decided to examine the Dapto records for evidence of circular polarization in such structure.

* Division of Radiophysics, CSIRO, University Grounds, Chippendale, N.S.W.

Table 1

DEGREE AND APPARENT PHASE OF POLARIZATION OF 20 TYPE II BURSTS, 9 OF WHICH CONTAIN HERRING-BONE STRUCTURE

Readings that refer to herring-bone or any other short-lived features are noted

Date		Starting Time of Type II Burst (U.T.)	Degree of Polarization	Apparent Phase of Polarization	Special Feature	Remarks
1959						
May	13	0516	moderate	circular	herring-bone	Far from type II core
July	14	0349	weak	linear†		
Aug.	28	0040	moderate	circular	short-lived feature	Bandwidth ~1 Mc/s
			weak	circular		
1960						
Feb.	18	0111	weak			
Apr.	28	0122	moderate		herring-bone	Far from type II core
			weak		herring-bone	Close to type II core
			weak			
Apr.	29	0213	weak			
May	13	0523	weak	linear†		
June	15	0305	weak	circular		
June	20	0138	weak	elliptical		
June	27	0007	no reading*	circular	herring-bone	Close to type II core
June	27	0423	strong		herring-bone	Far from type II core
			moderate		herring-bone	Close to type II core
			weak			
June	27	0503	strong		herring-bone	Far from type II core
			weak		herring-bone	Close to type II core
			weak			
July	26	0334	strong	circular	herring-bone	Far from type II core
Aug.	11	0258	weak	elliptical		
Sept.	2	0545	strong	circular	short-lived feature	Bandwidth ~1 Mc/s
			weak	linear†		
Sept.	26	0543	weak			
Nov.	15	0221	weak	circular		
1961						
Apr.	6	0017	no reading*	circular	herring-bone	Far from type II core
			no reading*	elliptical	herring-bone	Close to type II core
July	28	0234	weak		herring-bone	Far from type II core
			weak			
1962						
Aug.	14	0246	no reading*	circular	herring-bone	Far from type II core

* From the intensity of the phase pattern we would expect the degree of polarization to be moderate or strong.

† Linear polarization may result from ground reflections (see Section II).

II. Limitations of Observations

From the Dapto records for the period 1958 to 1963, sufficient information was obtained to study the polarization of 20 type II bursts, 9 of which contained herring-bone structure. A record of the dynamic spectrum from 5 to 210 Mc/s, the degree of polarization at either 40 or 60 Mc/s, and the phase of polarization from 40 to 70 Mc/s can be obtained every $\frac{1}{2}$ sec with the Dapto equipment. In practice, however, the degree and phase of polarization readings are time-shared with the measurements of source size and position. An excellent description of the Dapto instruments has been given by Sheridan (1963). A reliable measurement of polarization is only obtained for signals that are moderately or strongly circularly polarized. Faraday rotation in the corona and ionosphere (Akabane and Cohen 1961) is so high that a signal that was linearly polarized at emission appears to be unpolarized. Consequently any measured linear polarization is considered to have been caused by ground reflections.

III. Observations

The polarization data for 20 type II bursts, for which some or all of the records described in the previous paragraph exist, are given in Table 1 with a description of the spectral features involved. We have made the distinction between herring-bone features close to and far removed from the core of the type II burst. The degree of polarization has been called *weak* if less than 20%, *moderate* if between 20 and 40%, and *strong* if more than 40%. It can be seen from Table 1 that type II bursts without herring-bone structure in general (15 out of 17 cases*) exhibit weak polarization. On the other hand, when herring-bone structure is present the polarization is moderate or strong (5 out of 6 cases up to 70%) for frequencies far from the type II core. Closer to the type II core the polarization is weaker (3 out of 3 cases). Whenever a positive identification of the harmonic could be made it was found that the polarization readings referred to the herring-bone structure in the fundamental component of the type II burst.

An example of a type II burst containing herring-bone structure is given in Plate 1, together with a plot of the degree of polarization at 40 Mc/s (full line) and 60 Mc/s (dashed line). The herring-bone structure is present in the early stages of the event (0424 to 0429 U.T.) and is more developed on the low frequency side of the type II band. During this period the degree of polarization reaches a higher value at 40 Mc/s (40 to 60%) than that at 60 Mc/s (20 to 40%). However, the 60 Mc/s readings refer to herring-bone features much closer to the core of the type II burst. The lower degree of polarization for herring-bone features at 60 Mc/s is probably due to a contribution of much weaker polarized emission from the core. Indeed, later in the event when the herring-bone structure disappears the polarization at both 40 and 60 Mc/s drops to less than 10%, showing that the type II burst without herring-bone structure is only weakly polarized.

We conclude from the results presented above that the type II burst is only weakly circularly polarized and may indeed be completely unpolarized. However,

* The two exceptions are type II bursts containing very narrow-band (of the order of 1 Mc/s) short-lived features that are more highly polarized than the type II bursts themselves.

when herring-bone structure is present, features far from the central frequency of the type II burst can be strongly circularly polarized. Also, type II bursts sometimes contain highly polarized narrow-band features of short duration.

IV. Discussion

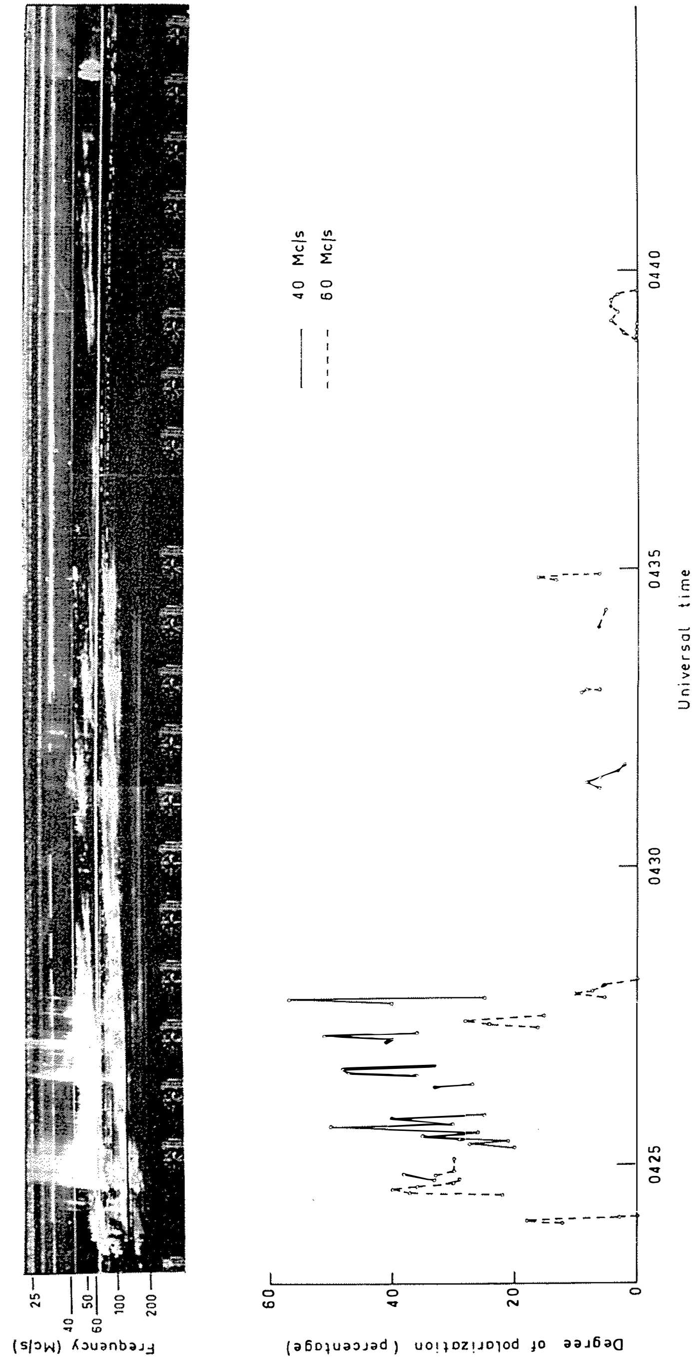
The observations of circular polarization in both fundamental and second harmonic components of some type III bursts led Komesaroff (1958) to the conclusion that the polarization was imposed at emission and not by propagation between the source and the observer. Unfortunately, we do not have sufficient data to determine whether the herring-bone features of type II bursts are polarized in the second harmonic as well as in the fundamental component. However, there is a striking resemblance in the dynamic spectrum of herring-bone features and polarized type III bursts, which tend to be of shorter duration than unpolarized type III bursts (Rao 1965). This resemblance suggests that the two phenomena are generated in a similar way.

Now the type III burst is supposed to result from oscillations in the corona at the plasma frequency (Wild 1950), due to the excitation of coherent Čerenkov plasma waves (Bohm and Gross 1949). These waves are thought to be excited by a pulse of fast electrons ejected from the lower corona during a solar flare. The conversion from longitudinal plasma waves to transverse electromagnetic waves may be accounted for by the scattering mechanism proposed by Ginzburg and Zheleznyakov (1958). An appealing feature of this mechanism is that it gives emission preferentially at the fundamental and second harmonic plasma frequencies in agreement with observations.

On the other hand, the source of the herring-bone feature, though similar to type III bursts, appears to be initiated in the disturbance responsible for the type II burst. This disturbance is thought to be a magnetohydrodynamic shock front, driven by a cloud of ions and electrons ejected from the flare region and capable of exciting plasma oscillations in the corona (Wild 1962). Wild (1964) has suggested that the herring-bone structure arises when the type II disturbance travels across a radially directed magnetic field. Some of the fast electrons produced by the disturbance could then escape from the type II source region along the radial field lines to both higher and lower regions of the corona and set up plasma waves. This model is very appealing as it explains not only the appearance of both positive and negative frequency drifts in herring-bone features but also the unusually slow drift rates (Wild 1964) often observed in type II bursts with herring-bone structure. Evidence for tangential source motion in herring-bone events has been given by Weiss (1963).

Apart from herring-bone structure, the only polarized elements in type II bursts appear to be features of short duration and very narrow bandwidth. We are tempted to draw a general conclusion that sharp short-lived features have a greater probability of being polarized than more extended features. This conclusion is consistent with the supposition that the sources of polarized events are highly localized, possibly by the action of a magnetic field, and that the polarization is imposed at the source region itself rather than by propagation between the source and the observer.

POLARIZATION OF TYPE II SOLAR RADIO BURSTS



An example of the spectrum and degree of polarization at 40 and 60 Mc/s of a type II burst containing herring-bone structure.

V. Acknowledgments

The author wishes to thank Dr. J. P. Wild and Dr. S. F. Smerd for valuable discussions, and many other members of the Radiophysics Laboratory for their assistance. In particular, the author is indebted to Mr. K. V. Sheridan and Mr. J. Joisce for excellent observations, and to Miss Bess Hardwick and Mrs. Sue Spiers for assistance with the analysis.

VI. References

Akabane, K., and Cohen, M. H. (1961).—*Astrophys. J.* **133**: 258.

Bohm, D., and Gross, E. P. (1949).—*Phys. Rev.* **75**: 1851.

Ginzburg, V. L., and Zheleznyakov, V. V. (1958).—*Astr. Zh.* **35**: 694. English translation *Soviet Astr.* A–J **2**: 653.

Komesaroff, M. M. (1958).—*Aust. J. Phys.* **11**: 201.

Rao, U. V. G. (1965).—*Aust. J. Phys.* **18**: 283.

Roberts, J. A. (1959).—*Aust. J. Phys.* **12**: 327.

Sheridan, K. V. (1963).—*Proc. Instn Radio Engrs Aust.* **24**: 174.

Weiss, A. A. (1963).—*Aust. J. Phys.* **16**: 240.

Wild, J. P. (1950).—*Aust. J. Sci. Res.* A **3**: 541.

Wild, J. P. (1962).—*J. Phys. Soc. Japan* **17** (Suppl. AII): 249.

Wild, J. P. (1964).—*In* "The Physics of Solar Flares." (Ed. W. N. Hess.) pp. 161–77. AAS–NASA Symp., 1963. NASA Publ. SP–50.

Wild, J. P., Murray, J. D., and Rowe, W. C. (1954).—*Aust. J. Phys.* **7**: 439.