POLARIZATION MEASUREMENTS AND MODELS OF SOLAR MICROWAVE BURSTS

A. KRÜGER

Central Institute for Solar-Terrestrial Physics (HHI)
of the Academy of Sciences of the G. D. R., Berlin, G. D. R.

Abstract: Based on results of statistical investigations of the polarization characteristics of solar microwave bursts and individual type IV burst interpretation facilities in terms of some most probable mechanisms for producing circularly polarized radiation have been discussed. Some consequences on the properties of flare models have been taken into consideration.

Introduction

There are some reasons for solar microwave bursts as well as X-ray bursts being directly related to the primary instability, causing the flare phenomenon. In this respect measurements and analyses of the polarization characteristics come more and more into consideration as a modern trend. It is well known that the microwave burst fluxes exhibit a variable fraction of circular polarization ranging, on the average, from zero to fifty per cent. Furthermore, it is widely believed that the emitted radiation refers to the extraordinary electromagnetic wave mode. However, a great number of bursts contradicts this conception, provided magnetic polarities, simply adopted from the leading spot hypothesis, are used. Early investigations (Tanaka and Kakinuma, 1959) based on a restricted material, demonstrated the great variety of possible cases. Since then little progress has been achieved. The present report is an attempt to clarify some hitherto obscured physical dependences, drawing on more extensive observations now available.

Polarization Characteristics of Type IV Bursts

The polarization of type IV bursts was first systematically investigated by Kai (1965). Regarding the type IVμ component, he found the degree of polarization of about 10—30 % to be nearly constant throughout an event and maximum degrees of polarization near the spectral intensity maximum. In some contrast to these results, the HHI observations indicate changing degrees of polarization (Fig. 1) as more typical for large type IVμ events. Also the spectral dependence of the

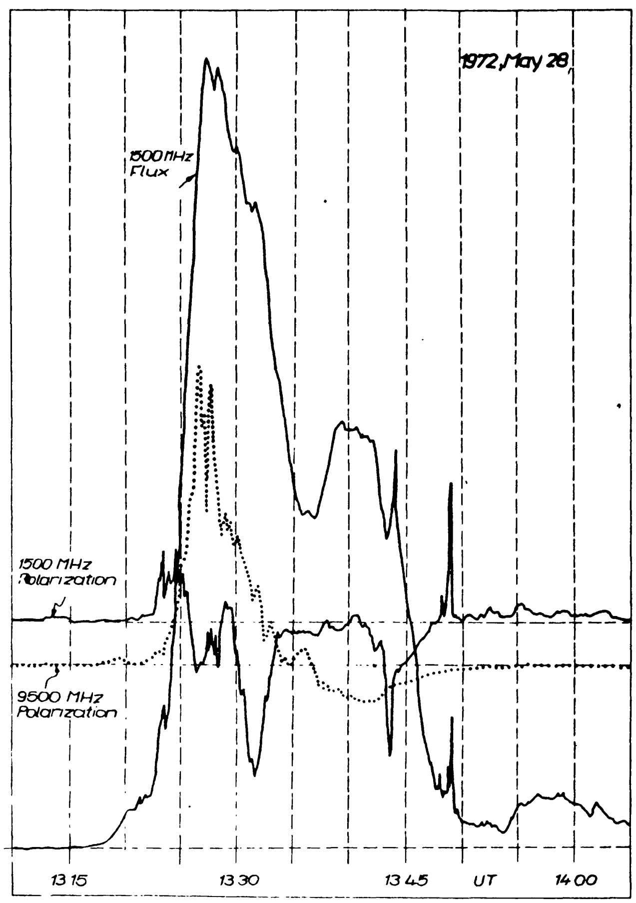

Fig. 1. Example of records of circular polarization (clockwise upward, anticlockwise downward) of a type IVμ burst at 1500 and 9500 MHz (HHI) from May 28, 1972.

degree of polarization does not seem to be very clear with regard to new observations, as well as to the theoretical model, including the synchrotron reabsorption proposed by Holt and Ramaty (1969). Thus, in general, we have to be aware of temporal and spectral changes, even reversals, of the sense of circular polarization, yielding a complicated picture of the changing polarities and concurrent processes.

For the purpose of investigating the systematic dependences, therefore, it seems appropriate to start with a study of the impulsive phase of large events which is hoped not to be affected so much by geometric effects (restricted areas) or, even better, to study statistically a greater number of simpler microwave bursts. The latter will be attempted in the following.

Polarization Characteristics of Microwave Bursts

In order to check the polarization characteristics of solar microwave bursts in dependence on the source location on the Sun, spectral form, and observing frequency, the observations of Nagoya, Japan, on 1.0, 2.0, 3.75, and 9.4 GHz have been statistically investigated for the period 1969—1972. The bursts have been devided into four spectral classes, according to the total flux spectrum:

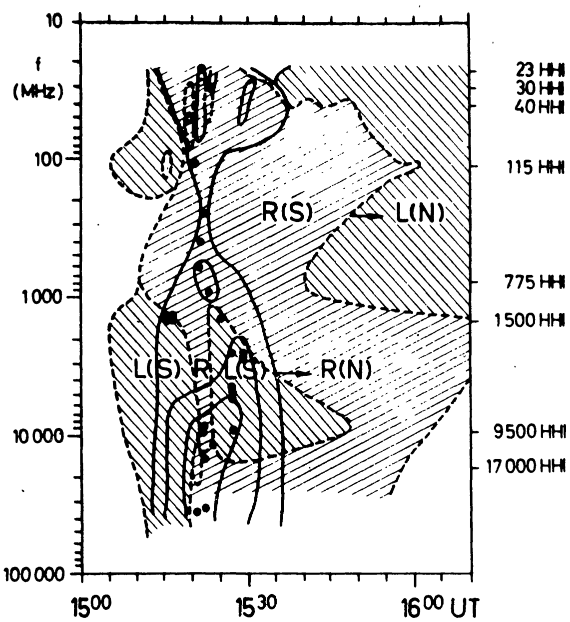

Fig. 2. Example of a polarization diagram of a type IV burst of August 7, 1972 (adopted from Křivský et al., 1976).

A : $f_{max} \geq 10{,}000$ MHz,
B : $f_{max} \leq$ 1000 MHz,
C : $1000 < f_{max} < 10{,}000$ MHz,
M : mixed types, e.g. AB, AC, etc.

With regard to the sense of circular polarization the following groups have been distinguished:

r — clockwise circular polarization,
l — anticlockwise circular polarization,
o — random polarization,
m — mixed polarization.

With respect to the location of the burst centres on the Sun, derived from associated flare positions for each (N-S) solar hemisphere, four classes of heliographic longitudes have been considered:

I: 90—40 E,
II: 40—0 E,
III: 0—40 W,
IV: 40—90 W.

From the results, derived from different statistical procedures, two statements may be made here which immediately follow from considering Tables 1—3.

Table 1 clearly shows a statistical dependence of the prevailing sense (and also degree) of polarization on the heliographic longitude of 9400 MHz bursts: in the northern hemisphere, approaching the east limb counterclockwise circular polarization is dominating, changing into clockwise circular polarization on approaching higher western longitudes. In the southern hemisphere the same tendency, but with reversed polarities, can be observed. It should be noted that this dependence results independently from the spectral class of the microwave burst. Table 1 demonstrates that, on the average, the leading spot hypothesis can only be applied, if the burst centres are located in the eastern hemisphere at a certain distance from the central meridian.

Turning to decimetric wavelengths, a systematic reversal of the sense of circular polarization is a common, well-known feature. This is also seen from Table 2 which shows the same picture as Table 1, but now for 1000 MHz, exhibiting opposite polarities. The longitudinal effect may again be seen.

As regards the observational frequencies of 3750 and 2000 MHz, naturally, the dependences, mentioned above, are more or less obscured by the spectral transition from one polarity to the other.

Finally, the relationships between the degree of polarization and different spectral classes of microwave bursts have been considered, and this is

Table 1. Distribution of 9400 MHz bursts (NAG 1969—1972)

Hemisphere			North					South		
Longitude	*r*	*l*	*o*	*m*	Σ	*r*	*l*	*o*	*m*	Σ
90—40 E	11	41	59	1	112	34	3	37	1	75
40— 0 E	22	39	74	2	137	32	10	64	1	107
0—40 W	37	26	68	3	134	24	21	48	1	94
40—90 W	41	10	47	—	98	5	21	25	1	52
					481					328
										809

Table 2. Distribution of 1000 MHz bursts (NAG 1969—1972)

Hemisphere			North					South		
Longitude	*r*	*l*	*o*	*m*	Σ	*r*	*l*	*o*	*m*	Σ
90—40 E	27	11	43	2	83	6	13	25	1	45
40— 0 E	33	20	37	10	100	9	25	36	7	77
0—40 W	26	6	31	3	66	11	11	28	1	51
40—90 W	15	23	33	3	74	12	3	21	1	37
					323					210
										533

Table 3. Polarization characteristics in dependence on spectral class

	9400 MHz					1000 MHz				
	r	*l*	*o*	*m*	Σ *rlm*	*r*	*l*	*o*	*m*	Σ *rlm*
A	92	78	180	3	173	10	20	49	3	33
B	9	9	21	—	18	35	30	32	7	72
C	58	37	124	2	97	27	27	83	4	58
M	47	47	97	5	99	67	35	90	14	116
	206	171	422	10	387	139	112	254	28	279
					809					533

demonstrated by Table 3. On the average, we find nearly an equipartition between polarized and unpolarized bursts on 9400 MHz. In particular, no preference of spectral classes A and C can be detected. But on 1000 MHz the bursts of spectral classes B and AB are significantly more polarized than of the other classes.

Conclusions

In principle, several processes are capable of determining the polarization properties of solar microwave bursts:

— balance of different source regions of opposite polarities (geometrical effect);

— the emission mechanism (gyro-synchrotron radiation, gyro-resonance absorption, synchrotron self-absorption influencing optical depths, etc.);

— wave propagation effects (mode transformation, absorption) (cf., e.g., Krüger, 1972).

Looking at these processes, the resulting longitudinal effect of the microwave burst polarization is in favour of the main properties of the Takakura-model of limiting polarization of the solar microwave emission, originating in bipolar source regions (Takakura, 1961) which could not as yet be fully proved by observations. The model was based on the single-particle synchrotron emission process involving electromagnetic mode coupling in a cold plasma as a propagation effect.

Concerning the strongly marked polarization effect at the high frequency side of the burst spectrum, the same behaviour was forecast by the Holt—Ramaty model of microwave bursts (Holt and Ramaty, 1969), taking into account the influence of increasing optical depths due to synchrotron self-absorption. However, if solely employed, this interpretation obviously fails with regard to the observed sense of polarization (e-mode predicted!). Neither could the inversion of the sense of polarization at the low frequency side of the microwave spectrum (class A at 9400 MHz!), proposed by the Holt — Ramaty model, be verified by the present investigation.

Concluding these remarks, it should be stressed that in many respect polarization studies open a fruitful field of research which should be intensified in future, giving the opportunity and stimulations for a synthesis of more extensive theoretical work with observations.

References

HOLT, S. S. and RAMATY, R. (1969): Solar Phys., *8*, 119.

KAI, K. (1965): Publ. Astron. Soc. Japan, *17*, 294.

KŘIVSKÝ, L., VALNÍČEK, B., BÖHME, A., FÜRSTENBERG, F., and KRÜGER, A. (1975): This volume.

KRÜGER, A. (1972): Physics of Solar Continuum Radio Bursts. Akademie-Verlag, Berlin.

TAKAKURA, T. (1961): Publ. Astron. Soc. Japan, *13*, 312.

TANAKA, H. and KAKINUMA, T. (1969): Paris Symp. on Radio Astronomy, p. 215. R. N. Bracewell (Ed.). Stanford Univ. Press.