Polarization Characteristics of a Group of Spectral Type III Solar Radio Bursts at 25 MHz Recorded on 14 July 1969

S. K. MATTOO, R. V. BHONSLE & S. K. ALURKAR
Physical Research Laboratory, Ahmedabad 380009

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A group of spectral type III solar radio bursts were recorded on 14 July 1969 by a time-sharing polarimeter which had a half-power bandwidth of ± 10 kHz and a time-constant of 1 sec. The purpose of this paper is to discuss the polarization properties of the two components, namely, the short duration bursts and background continuum radiation.

2. Polarization Characteristics of the Event

Figure 2 shows a four-channel polarimeter recording of the solar event observed between 0813 and 0815 hrs UT. The four channels represent the Stokes parameters, namely, I, Q, U and V, which completely define the state of polarization of radiation. One can distinguish at least 10 different peaks on the intensity channel denoted by I. It may be noted that the intensity of radiation does not drop to zero between 0813 and 0815 hrs UT.
the two successive peaks following the main peak. This could either be due to occurrence of bursts in quick succession or due to a simultaneous steady emission of background component with less variability. We favour the latter possibility in view of the fact that the average duration of individual type III bursts at 25 MHz has been observed to be about 10 s. Since the output time-constant of the polarimeter is about 1 s, the time profile of the intensity of type III bursts can be considered to be genuine.

Figure 3 (a-d) shows variation in intensity, degree of polarization, axial ratio, and orientation angle of the major axis of the polarization ellipse as a function of time. Values of $I$, $Q$, $U$, and $V$ were scaled from the polarimeter recording at the peaks and troughs of the intensity profile. For comparison the total intensity $I$ and the intensity of the polarized component of radiation $I_p$ are plotted on the same scale. It can be seen that $I_p$ is less than $I$ throughout the duration of the event. Thus, it can be concluded that the radiation was partially polarized.

Variation of the degree of polarization $m$ during this event can be seen in Fig. 3 (b). Errors in the measurement of $I_p$, $m$, $r$, and $\chi$ are of the order of ±5 per cent. It can be noticed that $m$ varied between 30 to 80 per cent during the event. From the time variation of $m$, it can be seen that $m$ decreases from about 0.8 to 0.4 between 0813 and 0814 hrs UT with a tendency to fluctuate by ±0.15 about its mean value. These fluctuations seem to correspond with those of the total intensity. In other words, it may be
said that this solar event consisted of two components of emission occurring simultaneously, the burst component that was weakly polarized and the background component that was strongly polarized. The dissimilarity in the degree of polarization of the burst and background components of radiation suggests (a) that they must originate in the coronal regions pervaded by weak and strong magnetic fields respectively and (b) that their mechanisms of generation could also be different.

Figure 3 (c) shows that the axial ratio \( r \) varied between \(+0.13\) to \(-0.18\). Initially the axial ratio was positive. But during the intense phase of the event, the axial ratio became negative and again returned to its positive value during the last phase of the event. Physically, it means that the total radiation was initially elliptically polarized in the left handed sense, with an axial ratio of about \(+0.13\) and changed to right handed sense, with an axial ratio of about \(-0.18\) when the burst component dominated. Thus, the change of sign of the axial ratio has occurred during the presence of the burst component. This implies a change in the polarity of the net magnetic field at the source region. Since we have already identified at least two components of radiation, namely, the weakly polarized burst component and relatively strongly polarized background component, the change in the sign of the axial ratio must be attributed to the background component. The instantaneous orientation angle, shown in Fig. 3 (d), changed by about 12° during the maximum phase of the event.

3. Discussion

It is clear from the dynamic spectrum and variations in polarization parameters of radio emissions associated with the solar flare of 14 July 1969, that the total radiation consisted of a weakly polarized burst component superimposed on a relatively strongly polarized background component. Such simultaneous occurrence of the burst and background components of radiation demands electron acceleration and release from the seat of the flare in different directions along the magnetic field lines. It is conceivable that some of the electrons which enter the closed magnetic field lines, get trapped and emit strongly polarized radiation (gyro-synchrotron process), while those electrons which escape freely along open field lines give rise to weakly polarized type III bursts (plasma oscillations). Careful examination of Fig. 1 reveals that the individual type III bursts in the group display slightly different drift-rates. The different drift-rates may arise due mainly to three possibilities since it is a function of stream velocity, direction of ejection of particles and coronal electron density gradient. Assuming that the stream velocity and electron density remain constant, the different drift-rates can be attributed to ejection of electron streams in different directions during the flare.

It has already been pointed out that the axial ratio changed from positive to negative values when the burst radiation was at its maximum intensity, and returned to its original positive value after the burst activity subsided. The change in the sense of rotation of the polarization ellipse is expected to occur if the burst radiation encounters a quasi-transverse (QT) region on its passage out from the source region to the observer. The QT conditions could exist in the corona and/or in the earth's ionosphere. Our computation shows that for the solar event observed around local noon at Ahmedabad (geogr. lat: 23°01' N; long: 72°36' E) the mode of radio propagation in the earth's ionosphere is always quasi-longitudinal. Under these circumstances, we expect that the effect of the earth's ionosphere is to cause only the Faraday rotation, unaccompanied by changes in the sign of axial ratio of the polarization ellipse. The observed changes in the axial ratio must, therefore, be attributed to the conditions peculiar to the source of radiation and/or propagation conditions in the solar corona. Assuming that the state of polarization is entirely due to the effects of propagation of radiation through the corona, the mixed polarization (\(R\) and \(L\)) may result if the radio emission originate from two different centres of activity; or even from only one center of activity. In the same paper Fokker has further shown that, in both cases the rays coming from source regions should not meet QT conditions above the center of activity. He pointed out that QT propagation conditions in the solar corona are more likely to occur when the source is near the limb than when it is in the central part of the solar disk. Taking into account the heliographic coordinates of the solar flare, assumed to be responsible for the radio event of 14 July 1969, the QT propagation effect of the coronal region away from the source may be ruled out as the cause of the change in the sense of polarization. Thus we conclude that the real cause of this change must be attributed to the source regions rather than the overlying propagation medium.

We would like to suggest that the observed change in the sense of rotation may be attributed to the background component. This can happen only when the source undergoes a shift in its position within the closed magnetic loop, where the field has opposite polarity. This shift in source position could be caused by excess pressure generated in the flare process. Alternatively, it could be that the burst and background radiation originated in two different
positions at the source with dissimilar magnetic fields and thus gave rise to the change in the sense of rotation. In other words, it means that the sense of rotation is determined by the burst component alone when the burst activity is intense and mainly by the background component when the burst activity is weak. To decide between the two possibilities high angular resolution observations are necessary. The telescope-type time-sharing polarimeter which we have used, is not suitable for high angular resolution observations. But the two-dimensional position determination made with the Culgoora radio heliograph operating at 80 MHz has revealed simultaneous existence of a number of burst sources on many other occasions. Our inference that the radio emissions associated with the solar flare of 14 July 1969 were due to simultaneous occurrence of two components originating from different regions is consistent with the model of the multiple burst source comprising type III, V, and U bursts proposed by Wild and Smerd.

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References