POLARIZATION OF SOLAR ACTIVE REGIONS
AT 3.5 MILLIMETER WAVELENGTH

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Abstract. A study of the circular polarization structure of solar active regions has been made from data obtained at 3.5 mm wavelength, using the 36 ft diameter radio telescope of the National Radio Astronomy Observatory at Kitt Peak, Arizona. The angular resolution of the telescope at this wavelength is 1'. All important active regions observed at 3.5 mm are bipolar in nature; the degree of polarization ranges from 1 to about 2%. These oppositely polarized components correspond with the Mt. Wilson magnetic regions of opposite polarity; the line of zero polarization delineates the neutral line between the regions of opposite polarity on magnetograms. The longitudinal magnetic fields at the level of 3.5 mm emission computed from the degree of polarization are found to be several hundred gauss.

1. Introduction

High resolution observations of the Sun have been made at 3.5 mm wavelength, during the period March 8–19, 1972, using the 36-ft diameter radio telescope of the National Radio Astronomy Observatory* situated at Kitt Peak, in Tucson, Arizona. The half-power beamwidth of the telescope at 3.5 mm is 1.2'. The telescope is equipped with a circular horn followed by a quarter-wave plate and a dual mode transducer. The quarter-wave plate is oriented at angles of ±45° to the orthogonal linearly polarized output ports of the dual mode transducer. In this arrangement a circularly polarized component in the incident radiation will appear as a linear component at one output port or the other, depending on the sense of circular polarization. The Dicke-type system with a ferrite switch connected to the output ports of the dual mode transducer measures the difference (L − R) between the left-hand and right-hand circularly polarized components of the incoming radiation. The total power (L + R) is recorded simultaneously with the (L − R) signal. Consequently, we have complete information on the circular polarization of the source being investigated.

The pointing of the two beams of opposite circular polarization appears to differ slightly; as a result, near the Sun's limb where the intensity rises or falls very steeply an instrumental polarization is introduced. This instrumental polarization is variable, but never exceeds 0.6%. For active regions close to the limb this instrumental polarization will be combined with the genuine polarization. For this reason, we have not attempted to measure polarization close to the limb. In this paper, we discuss some characteristic features of the polarization structure of the active regions at 3.5 mm wavelength.

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2. Observations

The observing procedure has been discussed previously (Kundu, 1970); it consists of scanning the Sun in right ascension at the rate of 1° per minute. Successive scans are separated by 1' arc in declination. The telescope is computer controlled and the program was set up to scan in a raster pattern, first to the East and then to the West. In order to provide sufficient baseline, the scans were chosen to be 45' long. A complete solar map done this way consists of a grid of $45' \times 41'$ in R.A. and declination.

The total intensity data were simultaneously recorded digitally and on analog charts; the polarization data were recorded on analog chart only.

Because of the difficulty of obtaining an absolute temperature calibration, or of determining accurately the beam efficiency of the antenna, we have assumed a mean temperature of 6400 K for the quiet Sun at 3.5 mm. The resulting contours in the completed maps have been normalized with respect to this value as explained in the figure captions. In the polarization maps, the polarization of the quiet Sun has been taken to be zero since the general magnetic field of the Sun is very weak. A total of about 40 complete total intensity maps have been obtained in this manner; we have also obtained a large number of active region maps of smaller extent in R.A. and declination. From the analog charts, a total of 8 polarization maps have been obtained.

3. Results and Discussion

Figures 1 through 3 show for some representative days during the period March 8–19, 1972 the total power $(L+R)$ maps and the polarization $(L-R)$ maps at 3.5 mm along with the Mt. Wilson magnetograms and Hz pictures.

A comparison of the $L-R$ maps with the corresponding $L+R$ maps shows that like the 9.5 mm regions (Kundu and McCullough, 1972a) each prominent active region in the total power map is bipolar in nature. The line of zero polarity or the neutral line often passes somewhere near the peak of the region. These features can be seen more clearly in the individual scans through active regions, as illustrated in Figure 4. There are also regions such as the ones marked X in Figures 2 and 3, where the polarity is predominantly of one sign.

Only three Mt. Wilson magnetograms were available for comparison with the 3.5 mm polarization maps obtained during this period. This comparison shows that all significant magnetic features of the magnetograms appear on the 3.5 mm $L-R$ maps and in most cases the millimeter and Mt. Wilson regions appear to be almost identical in extent. The $L-R$ regions have the same sense of polarity as the underlying magnetic regions; that is, positive $(L)$ and negative $(R)$ regions on the $L-R$ maps correspond to $-$ and $+$ (‘plus’ sign indicates the magnetic vector pointed toward the observer) magnetic fields on magnetograms. When there is only one dominant polarity on the magnetogram such as the ones marked X, there is also one polarity on the $L-R$ map.

The degree of polarization observed at 3.5 mm varies from 1 to 2% for the twelve