Variations in quiet sun radiation at centimetre wavelengths over 21st and 22nd solar cycles

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The variability of the total solar radio flux at five wavelengths, namely, 3 cm, 8 cm, 10.7 cm, 15 cm and 30 cm have been studied over 21st and 22nd solar cycles (1975-1991). The background component at these wavelengths has been estimated by eliminating the contribution of active regions on the measured total radio flux. This radiation is generally caused by thermal emission of the solar atmosphere and originates mostly from the chromosphere. The study of quiet sun radiation is of considerable importance since it helps to obtain the information on the electron density and temperature for different layers of the solar atmosphere. The present results indicate that at centimetric wavelengths the 'quiet' sun flux density and temperatures at the maximum activity are higher than the corresponding values at the minimum activity.

1 Introduction
The quiet sun radiation represents the radiation of the undisturbed static solar atmosphere. The undisturbed component has been observed to vary markedly during a solar cycle. Recent observations with high-spatial resolution have shown the existence of chromospheric fine structure mainly influencing the centimetre and millimetre wavelength radiations showing the importance of radio observations at these wavelengths to explain the variation of the quiet sun radiation at centimetre wavelengths.

2 Observations and analysis
The present paper provides the study of the quiet sun component of the solar radio emission during the period 1975-85 of 21st and 1986-91 of 22nd solar cycles at 3 cm derived from the radio observations of the sun carried out at Japal-Rangapur observatory, Osmania University, with the 10-ft radio telescope operating in Dicke mode. The radio telescope has the following characteristics.

- Frequency (GHz): 10
- Radiometer sensitivity (k): 0.5
- Integration time (sec): 1
- Total receiver noise figure (dB): 7
- Antenna dish diameter (m): 3
- Effective beam width (deg): 0.8

The complete period from 1975 to 1991 under investigation has been divided into 76 basic periods of 81 days. Each basic period of 81 days consists of three successive solar rotations, as the solar activity has been found to have 81-day periodicity. The quiet sun component of the solar radiation at 3 cm wavelength during each 81-day period is determined from the plots of the daily flux values against the sunspot number and by drawing a least square best fit line assuming the equation

\[ B_0 = B_0 + kR \]

where

- \( B_0 \) = Observed daily mean flux
- \( B_0 \) = Basic component corresponding to zero sunspot number
- \( k \) = A constant which is the slope
- \( R \) = Zurich sunspot number

The variation of quiet sun component of solar radio emission obtained from the observations at 3 cm wavelength taken with Japal-Rangapur radio telescope of Osmania University is presented as curve (a) in Fig. 1. The variations of this basic component derived at other wavelengths from the solar flux data taken from Solar Geophysical Data and Daily Reports of Solar Activity, Toyokawa Observatory, Japan, are also depicted in Fig.1 for comparison as curves (b), (c), (d), and (e).
Fig. 1—Solar flux density (in $10^{-22}$ W m$^{-1}$ Hz$^{-1}$) for different wavelengths as a function of time (Solid lines give the computed values for zero level of activity and dotted lines the observed mean values of solar flux density)
Variation of solar activity during the period of study is presented as curve (f). Figure 1 shows the variations of quiet sun component at all these five wavelengths averaged over 3 rotation periods comprising 76 basic periods during the period 1975-1991. We noticed a remarkable stability of quiet sun emission at all the centimetre wavelengths during solar minimum period, while there are considerable variations during the maximum period as found earlier by Lokanadham and Subramaniam. Furthermore, from Fig. 1 it is clear that the quiet sun component is high during 21st solar cycle than in 22nd cycle. This indicates that the 21st solar cycle is more active with wide
and intense sub-peak activity. The variations in quiet sun component with wavelength during 21st and 22nd solar cycles are presented in Figs 2 and 3, respectively. The corresponding variations in disc temperatures obtained by using the relation

$$T_d = \frac{S \lambda^2}{1.88 \times 10^{-27}}$$

where, $S$ the flux density at wavelength $\lambda$, during 21st and 22nd solar cycles are also presented in Figs 2 and 3, respectively.

3 Discussion and conclusions

From the study of the frequency spectrum as a function of time we found that the apparent disc temperature varies considerably at higher
Table 1—Changes of apparent disc temperature at different wavelengths as observed during the two solar cycles

<table>
<thead>
<tr>
<th>Wavelength (cm)</th>
<th>21st solar cycle</th>
<th>22nd solar cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>3</td>
<td>0.138</td>
<td>0.161</td>
</tr>
<tr>
<td>8</td>
<td>0.262</td>
<td>0.407</td>
</tr>
<tr>
<td>10.7</td>
<td>0.425</td>
<td>0.755</td>
</tr>
<tr>
<td>15</td>
<td>0.634</td>
<td>1.268</td>
</tr>
<tr>
<td>30</td>
<td>2.110</td>
<td>4.667</td>
</tr>
</tbody>
</table>

wavelengths. These changes of apparent disc temperature \( T_d \) in percentage at different wavelengths during 21st and 22nd solar cycles are presented in Table 1.

There is a remarkable stability of the values of the basic component for the years of low solar activity, while it exhibits considerable fluctuations during the years of high solar activity. We can classify two different types of spectra by following the nature of the spectra in Figs 2 and 3. The first one corresponds to the high activity period and the second to the low activity period. It is seen from Figs 2 and 3 that the apparent disc temperature \( T_d \) increases with increase in wavelength, while the basic component decreases. This indicates clearly the thermal nature of the quiet sun component \( B_0 \) at cm wavelengths. We can explain the changes of the quiet sun during a solar cycle by two different ways—one from variations of the effective solar radius, and the other from variations of the brightness temperature produced either by variations of the electron temperature or the electron density. But differences of the apparent temperature \( T_d \) between a maximum and a minimum of solar activity are too large to be explained by variations of the effective solar radius. Hence, it leads us to attribute these variations to the second case. These observations are consistent with the observations of Giannina Poletto\(^2\) and Dialetis et al.\(^3\)

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References