A Comparative Study of Equatorial Radio Source Scintillations & the Scintillations Expected for ATS-6 Emissions over India

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The large radio telescope system at Ootacamund near the geomagnetic equator is used with advantage to study the ionospheric scintillations in the equatorial belt. Several narrow diameter radio sources were observed with the above system and some preliminary scintillation results at 327 MHz are reported. The scintillation indices derived from the actual records are compared with the existing Fremouw & Rino global model. The model grossly underestimates the scintillation indices by as much as one order of magnitude at low solar activity levels. Various possible reasons for the inadequacy of the above said model are discussed. Further, in view of the Indian SITE programme on 860 MHz from the ATS-6 satellite, the expected scintillation indices based on Fremouw & Rino model at various centres in India are calculated. However, due to the inherent discrepancy in the calculation of the values for radio source scintillations from the above model, these expected scintillation indices for the SITE programme should be viewed with caution.

1. Introduction

The era of satellite communication has brought in increasingly greater interest in the amplitude and phase fluctuations of radio waves that are caused by irregular structures in the ionosphere. In spite of the fact that the equatorial zone has a strongly scintillating belt over it, the data on equatorial scintillations are very meagre. To summarize all the information we have from a few studies made on equatorial scintillations, there is a very strongly scintillating belt with a total width of 30° latitude centred around geomagnetic equator with fading rates much lower than those of the auroral type of scintillations, and caused by irregularities of a few hundred metres in extent moving with speeds of 70 to 140 m/sec at a mean altitude of 300 km. The scintillation activity is expected to be maximum during equinox and between 2000 and 2400 hrs local time. With India’s involvement in satellite communications, it is essential to obtain more data on equatorial scintillations from stations located within India. An elaborate collaborative project in this area was undertaken by the National Physical Laboratory, New Delhi, and the Tata Institute of Fundamental Research, Bombay, to take advantage of giant radio telescope at Ootacamund (Ooty), which has a north-south aperture dimension of 530 m and which is situated near the geomagnetic equator, well within the scintillation belt. Further, with the shifting of the ATS-6 satellite to 35°E longitude in Aug. 1975, it has become possible for several groups in India to use the ATS-6 emissions for scintillation studies. The main objectives of this paper are: (i) to report some preliminary scintillation results observed at Ooty while tracking the radio sources at 327 MHz, (ii) to compare these results with the existing Fremouw and Rino global model, and (iii) to estimate the scintillation indices that may be expected from the Fremouw and Rino model for the years 1975 and 1976 for ATS-6 beacon transmissions.

Fig. 1—A sample record of radio source 0859-25 received on 327 MHz at the Radio Astronomy Centre, Ooty, on 14 March, 1974 showing the commonly occurring deep ionospheric scintillations
2. Results

A very large number of very deep scintillations were recorded during 1973-75 at Ooty (geomag. lat., 2°20' N) from various radio sources on 327 MHz and detailed investigations of these records are under progress. However, the most important point to be mentioned in this context is that the scintillations during most of the nights and sometimes during daytime were much deeper than can be expected for low solar activity. A sample record of the radio source 0859-25 at 327 MHz obtained on 14 Mar. 1974 is shown in Fig. 1. The periods Feb.-Apr. and Sept.-Nov. are observed to be the months when frequent scintillations occur. The fractional r.m.s. fluctuations of received amplitude ($S_2$) and power ($S_4$) were calculated for a number of such records. Fig. 2 shows the variations of scintillation index with local time on two particular nights. These two records were chosen because they represent two different groups of scintillation data which can be clearly defined. The first group is represented by the dotted line, wherein there is very little average variation with local time and the entire night manifested several bursts of random scintillations. Most of the observations belong to this group. The second group of records, represented by the continuous line, show a general decrease in scintillation activity as the night progresses, reaching very low values after midnight. It is clear that these two groups of data possibly have two different mechanisms causing scintillations. Fig. 3 shows a comparison of the observed scintillation indices on 11 Nov. 1974 with the scintillation indices expected from Fremouw and Rino model for that particular epoch of solar activity, season and local time. It is obvious from Fig. 2 that the model grossly underestimates the scintillation indices by as much as one order of magnitude at certain times. This large disparity between the model values and the observed values is found to be very common.

In the context of the discrepancy shown above, it will be interesting to observe the scintillation indices that will be obtained in the near future from various beacon experiments that are currently in operation in India using the ATS-6 transmissions at 40, 140 and 360 MHz. It will take quite some time before the actual results are published; but to aid the experimenters in comparing the results with the only existing global model of scintillations, i.e. the Fremouw and Rino Model, some predictions based on the model are presented here. The computer programme developed at the Stanford Research Institute by Beaujardiere and McNiel based on the model of Fremouw and Rino was used to compute the scintillation indices at a few frequencies for the ATS-6 elevation angle at Ooty for a sunspot number 20. Fig. 4 shows the scintillation index variations with...
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local time for all the three frequencies and Fig. 5 shows the seasonal variation, while Fig. 6 gives the solar epoch variation.

3. Discussion

The large ionospheric scintillations observed at Ooty at 327 MHz as against the very weak scintillations expected from Fremouw and Rino Model suggest that the model probably is inadequate for low latitudes. It should be remembered that the model of Fremouw and Rino was meant to give an overall picture of global morphology, and that the accuracy for any geographical region essentially depends upon the statistical significance of the observational data fed into the model from that particular region. The only equatorial data fed into the model was from Accra, Ghana (geomag. lat., 9.4°). It is very significant to note that the data consisted of only one frequency (136 MHz) and for a particular solar epoch (sunspot number 100). This means that in the equatorial region, the model has practically no input for variations with latitude, solar cycle and frequency. In spite of Elkins' results, such a steep dependence on solar activity at the equator is rather surprising, while at mid-latitudes the scintillation index is known to be almost independent of solar activity. It is also possible that the frequency dependence in the equatorial belt may be entirely different. For example, if the irregularities are smaller and if their slant distances are greater, then the scintillation index \( S_2 \propto \lambda^1 \) (spectral index is unity). This will make the scintillations even at higher frequencies considerably large.

In view of the Indian SITE programme (860 MHz) using the ATS-6 satellite, we have computed the expected scintillation indices again using the above-mentioned model. The capitals of the states for which the SITE is intended and the respective \( S_2 \) values are listed in Table 1. It may be seen that at all stations the predicted indices of scintillation are insignificant and these apparently insignificant values

![Figure 5](image)

**Fig. 5** — Seasonal variations of the scintillation index \( (S_2) \) as computed from the Fremouw-Rino model for the ATS-6 transmissions received at Ooty (The origin coincides with the beginning of the calendar year)

![Figure 6](image)

**Fig. 6** — Sunspot number variations of \( S_2 \) for the ATS-6 transmissions for a local time of 0200 hrs on a December day at Ooty

### Table 1 — List of Stations Included in the SITE Programme, Their Geographical Coordinates and the Values of Scintillation Indices Expected from the Fremouw-Rino Model at 860 MHz

<table>
<thead>
<tr>
<th>Station</th>
<th>Geogr. lat.</th>
<th>Elevation angle</th>
<th>Scintillation index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangalore (Karnataka)</td>
<td>13°6</td>
<td>39°2</td>
<td>0.05</td>
</tr>
<tr>
<td>Hyderabad (Andhra Pradesh)</td>
<td>17°3</td>
<td>37°2</td>
<td>0.04</td>
</tr>
<tr>
<td>Bhubaneswar (Orissa)</td>
<td>20°33</td>
<td>28°7</td>
<td>0.04</td>
</tr>
<tr>
<td>Bhopal (Madhya Pradesh)</td>
<td>23°04</td>
<td>37°0</td>
<td>0.00</td>
</tr>
<tr>
<td>Patna (Bihar)</td>
<td>25°65</td>
<td>27°7</td>
<td>0.00</td>
</tr>
<tr>
<td>Delhi</td>
<td>28°66</td>
<td>33°5</td>
<td>0.00</td>
</tr>
</tbody>
</table>

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may be misleading because of the inadequacy of the model for low latitudes. Of course the main reason for the low indices is the low solar activity expected during 1975-76. However, for reasons mentioned above, the low values cannot be viewed with complacency; under conditions of strong scattering, the spectral index, which defines the wavelength dependence of scintillation index, will be unity or even less and the computations extrapolated from lower frequency observations will be misleading. This will be particularly true during high solar activity period and the transmission frequency may have to be shifted to a much higher one. This highlights the urgent need for measuring scintillations at equatorial latitudes over a number of frequencies extending to the GHz range.

References