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New Methods of Separating F Region Absorption From the Cosmic Radio Noise Absorption

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Abstract. A comparison of cosmic noise absorption data with pulse absorption and the absorption derived by using CW transmitters has given some interesting results. New techniques have been suggested to separate out the absorption contribution of the F region from the total cosmic noise absorption. A comparison of the F region contribution thus derived by the above techniques is fairly consistent with other classical techniques of separation. The electron temperautre derived from the above F region absorption compare well with the temperature obtained from more sophisticated techniques. Further the electron density profile (in the lower iono sphere) derived from the lower region absorption using the above technique has given comparable values with rocket and other theoretical profiles.

Key words: Cosmic radio noise – Riometer absorption – Pulse reflection technique – C.W. waves – Solar cycle – Sunspot number – Magnetic storm – Window effect – Electron temperature – Electron density.

1. Introduction

In the present investigation the authors have realised the importance of comparing riometer absorption (A_2) with pulse technique (A_1) and with the absorption derived from CW waves from commercial transmitters (A_3). Simultaneous use of any of the above two techniques with sunspot number has led us in developing a new technique of separating the F region contribution from the total riometer absorption. Riometer absorption is an integrated effect on the radio wave passing through the whole ionosphere. With proper separation techniques, valuable information can be derived regarding the various regions of the ionosphere. Mitra and Shain (1953) have developed a method of separating the relative contributions of the F and D regions. This involves a fundamental assumption, namely, the shape of the curve relating to absorption and f_oF_2 remains the same irrespective of the time of the day. Later Lusignan (1960) extended this technique by correlating the absorption with f_{min} and thus separated the D region contribution. However, by these techniques the D and E (lower) region contribution is overestimated by underestimating the contribution from the

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F region and above. Krishnamurthi and Sarma (1967) modified the above method to get more dependable results. This is discussed quite elaborately by Sarma and Sharma (1972).

Another approach of separating the F region absorption is to compare the simultaneous observations of riometer and pulse technique at the same station as reported by Taubenheim et al. (1966) during solar eclipse. When this technique was tried for the station Neustrelitz, even though there is a linear relationship between the (A_2) and (A_1) absorption we landed in difficulties as there remained a residual absorption on A_1 when the A_2 absorption is zero for which no plausible justification could be put forward.

To avoid this difficulty we extended this technique by comparing A_3 (oblique incidence method) with A_2 (riometer) for the same station and obtained fruitful results which will be explained in later sections. It was shown earlier by Sarma et al. (1970) and Mitra et al. (1970) that riometer and pulse absorptions behave differently with sunspot number. This fact was utilized in the present investigation in separating the F region contribution from the total absorption. The main limitation of this method is that one needs observations on both techniques over a complete solar cycle or at least a substantial part of it.

2. Data Analysis and Selection

In order to separate the F region contribution from the total cosmic radio noise absorption we have used the riometer, pulse and oblique incidence absorption (A_2, A_1 and A_3 techniques respectively) data for three stations Delhi, Ahmedabad and Neustrelitz to cover the period of IGY, IQSY and IASY. In all the cases the monthly mean values are used as the raw data by any two techniques for the analysis at different stations. The authors have eliminated directly the data taken during anomalous winter days, during magnetic storms and disturbed days and any other unreliable conditions. While considering the A_1 absorption data the frequency selection was such that the pulse is reflected back from around 100 km so that the absorption suffered by the pulse is mainly due to D region where the electron collision frequency exceeds the observing radio frequency of the pulse. Also care is taken to remove the deviative component of absorption when it occurs at certain time intervals. It was also observed for Delhi that in the case of riometer absorption (A_2) the window effect is almost non-existing during 95% of the time and during the rest of the period (especially during IGY) the effect is almost negligible as this is within the experimental accuracies and when it exists appropriate corrections were applied for Ahmedabad and Neustrelitz data.

Earlier it was shown by Sarma et al. (1970) that the relationship between the F region absorption (by A_2 technique) and $f_o F_2$ is the same for all the hours of the day and season. Further we could not establish any definite relationship between the absorption and the thickness of F region with our data and as such it was presumed that the layer thickness does not play a significant role in the F region contribution of absorption even though we expect the F region absorption to vary in proportion to the product of $f_o F_2$ raised to a power (exponent n) and the thickness of the F region. Earlier, Mitra and

Shain (1953) also reported that there is no correlation of F-layer thickness with the observed absorption. As we have observed that this exponent value differs from station to station and also with solar epoch conditions we feel that the F region thickness at any particular station may be taken care by the value of the exponent that is observed at different stations as it is invariably quoted by many investigators which is not equal to the expected value of the fourth power. With these selection criteria and observation we report our results below.

3. Experimental Results and Discussion

We have plotted A_2 absorption against sunspot number in the Figure 1. In the same plot the A_1 absorption converted to A_2 frequency by using the inverse square relationship (Sarma and Sharma, 1972) is also plotted and is normalized to zero sunspot number. The line depicting the A_1 absorption is mainly due to the D region and that of A_2 absorption is due to the entire ionosphere. The difference between these two lines gives the F region contribution corresponding to that sunspot number. So one can get a set of values of F region absorption against sunspot number which can be directly related to f_oF_2 values. For this we plot in Figure 2 the difference between the A_2 and A_1 absorption (scaled upto A_2 frequency) as a function of sunspot number, as well as average f_oF_2 values. The f_oF_2 values can be read out from this curve and thus establish a relationship between AF and f_oF_2. A similar type of analysis was carried out for Ahmedabad and the results are in good agreement as obtained for the station Delhi. However, for Neustrelitz this method did not give encouraging results.

After establishing the relation between F region absorption and f_oF_2 our next step was to use this F region absorption in deriving some physical parameters like electron temperature and electron density. We have calculated the

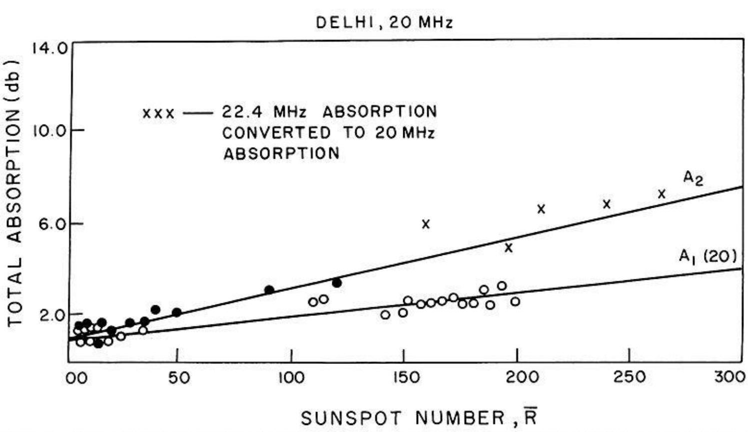

Fig. 1. Comparison of riometer (A_2) and pulse (A_1) absorption (scaled up to the riometer frequency) with sunspot number for Delhi

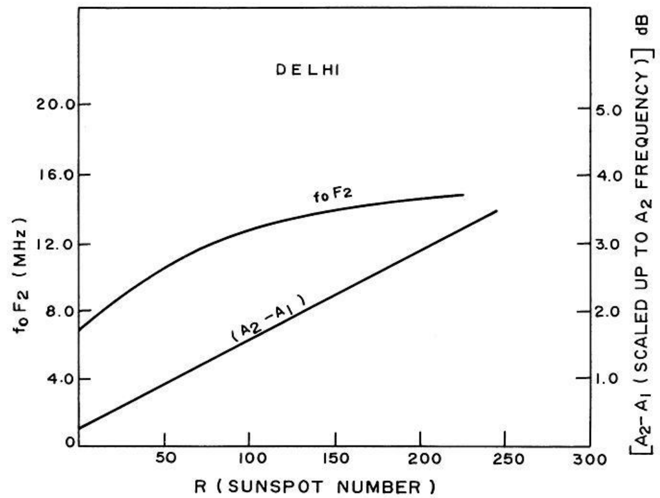

Fig. 2. Comparison of the difference in absorption (by riometer and pulse techniques) and foF2 with sunspot number for Delhi

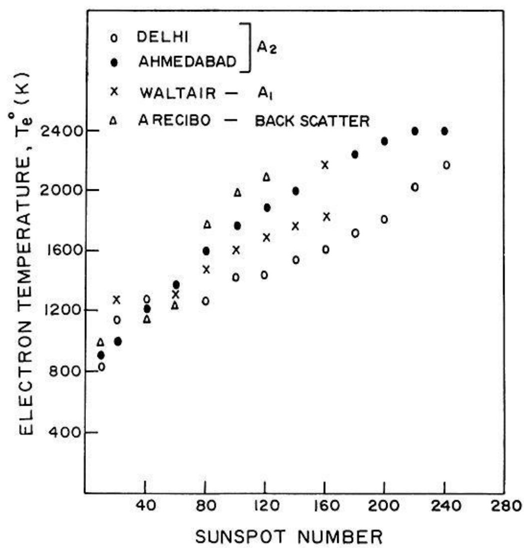

Fig. 3. Comparison of the derived electron temperature from riometer data with other insitu techniques at various sunspot numbers

electron temperature at the height of peak electron densities in F region under certain assumptions as reported by Sarma and Sharma (1972). The derived electron temperature against sunspot numbers are shown in Figure 3. In the same figure the electron temperature reported by Reddy et al. (1972) and the temperature measured by incoherent scatter technique at Arecibo is also shown. We see from the figure that the electron temperature derived by F region absorption is consistent with the temperatures derived by other techniques. This shows that F region absorption thus separated is dependable and reliable.

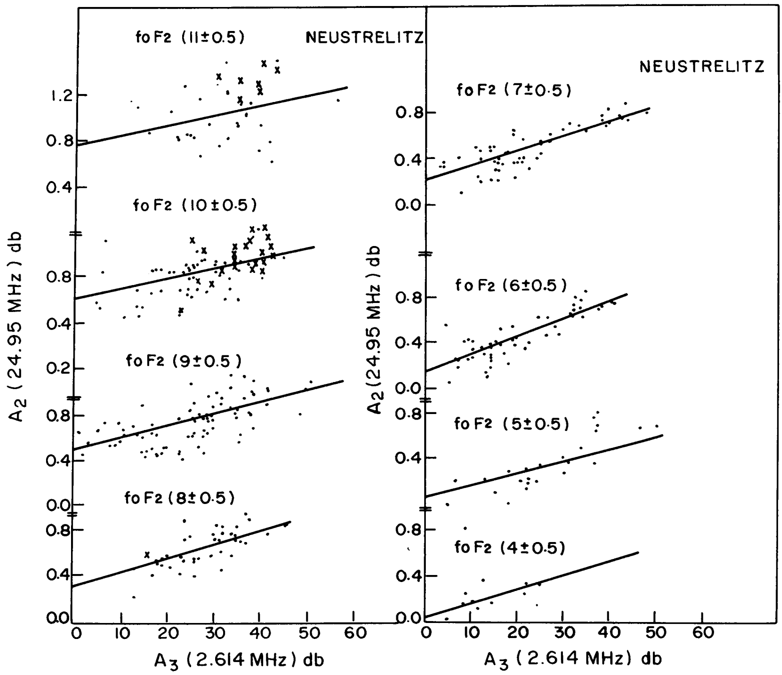

Fig. 4. Comparison of riometer absorption (A_2) with the absorption derived from CW transmissions (A_3) at various foF2 values for Neustrelitz

Another attempt has been made to separate the F region absorption by comparing A_2 and A_3 absorption as the A_3 method essentially measures the absorption from D region. For Neustrelitz the absorption data are available for all the three techniques A_1, A_2 and A_3. So we have compared the A_2 absorption with A_1 and A_3 absorption separately. There is a very good correlation between A_1 and A_3 absorption as reported by Mitra (1970) and this is expected as these two techniques essentially measure lower region absorptions. Hence by comparing A_2 absorption with either of A_1 and A_3 will enable us to separate the F region absorption from total absorption. The A_2 absorption is plotted against A_3 absorption for different slabs of f_oF_2 in Figure 4. As seen from the figure that when A_3 is zero, A_2 is not zero. This residual A_2 absorption is mainly due to the F region determined by the corresponding values of f_oF_2. It is also clear from the figure that the intercept on the A_2 axis goes on increasing with increasing values of f_oF_2. Hence a relation is established between absorption and f_oF_2. From the values of f_oF_2 one can directly get the F region absorption.

The lower region A_2 absorption is utilized in deriving the electron density distribution in the lower ionosphere. To do this we have chosen an appropriate reference electron density profile from Mechtly et al. (1972) from rocket measurements and the collision frequency is calculated from the pressure data given in CIRA (1965). The absorption is calculated from 60 km to h_mE and compared with the observed absorption. The reference electron density profile is shifted

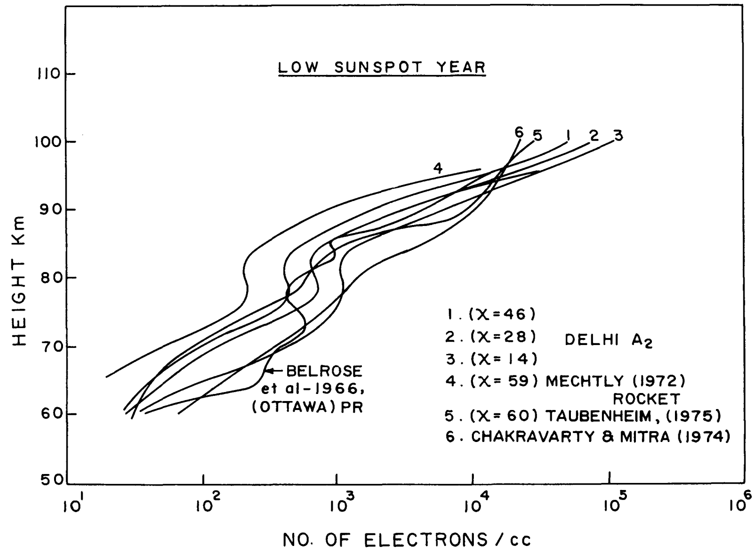

Fig. 5. Intercomparison of the electron density profile derived from the riometer absorption during low sunspot period for Delhi with other techniques

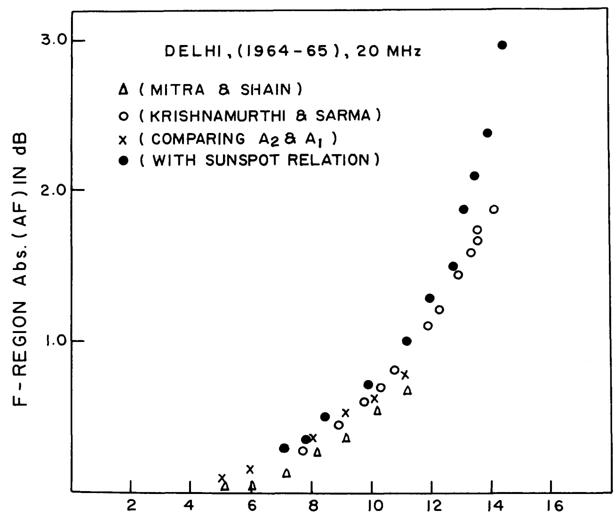

Fig. 6. Intercomparison of various methods of separating the F region absorption from riometer data

iteratively till the observed and calculated absorptions match. Such a profile consistent with the observed absorption is shown in Figure 5. In this figure the theoretical model of Mitra and Chakrabarty (1974) is also shown. In the same figure the profile by Mechtly et al. (1972) from rocket measurements is also shown. From the figure we see that the profile by A_2 absorption is consistent with that obtained by other sophisticated techniques. This shows that the lower region absorption can be used as a check point on models or to derive the day-to-day variation in electron density in the lower ionosphere. The F region absorption thus separated by these techniques is compared with other methods of separation as shown in Figure 6. It is evident from the above figure that the Mitra and Shain method shows a lower value of F region contribution (for the same f_0F_2 as expected). The other methods give comparable values essentially the same value within the experimental accuracies which seem to be more dependable.

3. Conclusions

Simultaneous use of riometer absorption (A_2) and any absorption measurement like pulse reflection technique (A_1) or use of c.w. waves from commercial transmitters (A_3) has given new methods of successful separation of the F region absorption from the riometer data. The F region contribution derived by the above techniques is shown to be dependable, as the electron temperature derived from F region absorption and the electron density derived from the lower region absorption are in consonance with those obtained by more sophisticated techniques.

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