IONOSPHERIC ABSORPTION STUDIES BASED ON COSMIC NOISE DATA AT 28·6 MHz AT BANGALORE

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Summary

Using a fairly narrow beam antenna (10°·5 by 16°·5), cosmic radio noise at 28·6 MHz has been continuously recorded during the years 1962–64. The data between midnight and 06 hr local time were used to determine the "unabsorbed cosmic noise intensity" for different sidereal times. Based on this, the total ionospheric absorption at this frequency was computed for the rest of the day. Diurnal and seasonal variations are discussed. The electron density and collision frequency profiles obtained by ionosonde, rocket, and incoherent backscatter techniques for various low latitude stations for the height range 40–800 km have been used to assess the relative contributions to the ionospheric absorption by different regions of the ionosphere. It is shown that at this frequency nearly half of the absorption is due to the topside ionosphere, a third is due to the F_2 layer, and the remainder is due to the lower regions, both D and E layers contributing almost equally. The ionospheric absorption during the late evening hours before midnight was found to be closely correlated with $f_0\,F_2$. It is shown that the total absorption during the rest of the day could be expressed as

$$A = b(f_0\,F_2)^2 + c f_{\min}^{2\cdot 2} + d.$$

I. INTRODUCTION

Continuous monitoring of cosmic radio noise at metre wavelengths has a number of advantages in the study of ionospheric absorption. Firstly, need for powerful and highly stable transmitters is eliminated; secondly, cosmic noise may be considered to originate from extremely stable sources; thirdly, contribution to absorption by the regions of the ionosphere above the F layer can also be studied. However, the main problems involved in using cosmic noise for ionospheric absorption studies are the difficulty of determining the "unabsorbed cosmic noise intensity" and the difficulty of having a suitable antenna to give a narrow beam at metre wavelengths. Also, the uncertainty in separating the contributions from the different ionospheric regions is not easy to eliminate. In spite of the difficulties mentioned above, riometers have been widely used for determining the ionospheric absorption from cosmic noise studies. However, the results obtained have to be taken with a great deal of reservation as most of the beamwidths used are of the order of 60° to 100°. The absorption studies in these cases are therefore not confined to the vertical direction alone but give a highly averaged-out behaviour of a large area of the ionosphere that falls within the beam of the antenna. The authors have therefore set up a fairly narrow beam antenna and have recorded cosmic noise at a frequency of 28·6 MHz. Some of the results of the studies carried out during the years 1962–64 at Bangalore (lat. 12° 58′ N., long. 77° 35′ E.) are presented here.

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II. Equipment

The antenna consists of a broadside array of 30 full-wave dipoles spread over an area of $3\,\lambda$ by $4\cdot 5\,\lambda$ backed by a ground wiremesh reflector. It has a beamwidth of $10^\circ\cdot 5$ in the east–west and $16^\circ\cdot 5$ in the north–south directions about the zenith, and is matched to a stable low noise receiver followed by a d.c. amplifier recorder system. Provision is made for periodical checks of the matching and stability of the receiving system, which is calibrated at regular intervals during the day with a noise generator using a temperature-saturated diode CV 2171. The antenna pattern has been computed and also experimentally verified on a number of occasions when there was intense solar activity of type IV continuum noise.

III. Experimental Results

In view of the beamwidth of the antenna, the cosmic noise recorded may be taken to be that due to the general sky background and not to any point sources, whose contribution to the total noise received will be negligible. The antenna scans a narrow strip of sky about $16^\circ\cdot 5$ in width along the declination of approximately 13° N. Data were collected from August 1962 to April 1964. In utilizing these data, all records that contained observed interference due to transmitters, lightning, and other effects were eliminated. The data were first used for the determination of the unabsorbed cosmic noise to be expected from the different parts of the sky, as described in the following paragraph, and this information was then utilized to obtain the ionospheric absorption at different times of the day.

It has been generally observed (Ellis 1963) that the effect of the ionosphere on the cosmic noise received will be negligible if the critical frequency of the F_2 layer is less than one-third of the observing frequency. As the present observations were carried out during a period of low solar activity, the critical frequency in the hours from midnight to 06 hr local time was always found to be much less than one-fifth of the observing frequency. Therefore the cosmic noise corresponding to any particular sidereal time was tabulated for the periods that fell within this interval of the day and an average for the particular sidereal time was determined. It was found that the equivalent noise current thus determined for any sidereal time did not fluctuate by more than 7% of the average. The average equivalent noise current at half-hour intervals for the entire sidereal day has been determined and hourly values are shown in Figure 1. The scatter in the observations, which have been used for determining the average values, is also indicated in this figure. With the absolute cosmic noise intensities corresponding to the different sidereal times thus determined, all departures from these values greater than the scatter have been taken to be due to ionospheric effects.

Total ionospheric absorption has been calculated at hourly intervals for the period 07–23 hr Indian Standard Time (I.S.T. is $5\frac{1}{2}$ hr ahead of G.M.T.), the period between 00 and 06 hr having been used for determining the absolute intensities. The accuracy of the results in the present investigation was estimated using an IBM 1620 computer. The results of the hourly values of absorption obtained by the above-mentioned technique were fed to the computer to obtain the statistical analysis of variance for each month. From the computed results the probable error involved in the estimation of the average absorption for each hour in a month was found to be $\pm 0 \cdot 1$ dB; that is, if $\bar{Y}$ is the estimated value from the fitted regression equation for any given value X, then the true value is expected to be $\bar{Y} \pm S_Y$, with 90% confidence, where S_Y is the residual standard deviation of $\pm 0 \cdot 1$ dB mentioned above. Thus an accuracy of $\pm 0 \cdot 1$ dB has been achieved for the results of the present investigation.

From the hourly values of absorption for each day, the monthly mean values have been computed. In Figure 2 the results for each month are plotted against Indian Standard Time. These results have been analysed and are discussed in the following section.

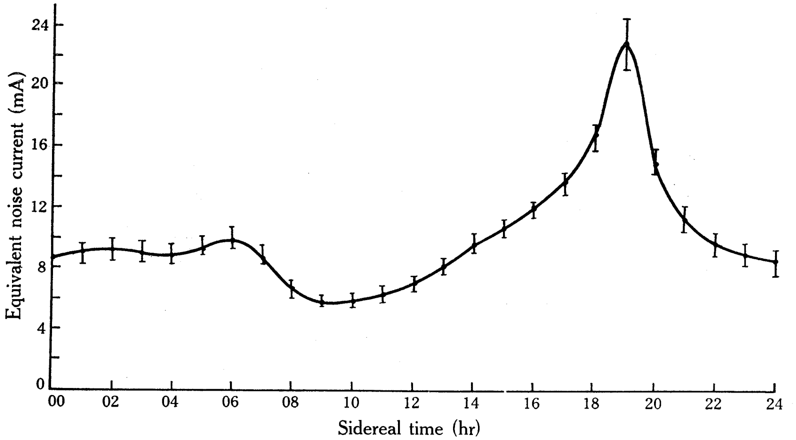

Fig. 1.—Scatter diagram of unattenuated cosmic noise intensity at 28·6 MHz for an entire sidereal day.

IV. Discussion

(*a*) *Diurnal Variation of Total Absorption*

It can be seen from Figure 2 that the total absorption on no occasion exceeded a value of 2·0 dB and most of the time was much less. Considering the high frequency used and the period of low solar activity during the investigation, the result agrees well with those found by other observers, e.g. Mitra and Shain (1953) and Anastassiades (1963). However, Checcacci and De Giorgio (1964) have reported a value of only 0·7 dB for the maximum absorption at a frequency of 27·6 MHz during the years 1961–62. It may be noted that all these other measurements were carried out during the same portion of the solar cycle. Mitra and Shain (1953) reported the same order of absorption values, even though the results were obtained at a lower frequency (18·3 MHz). However, Sarada and Mitra (1961) and Bhonsle and Ramanathan (1961) have reported higher values of absorption (4–5 dB) in all seasons. The reason for their higher values may be the fact that they worked in the period of maximum solar activity, whereas the present work was carried out in the period approaching minimum solar activity, and also to some extent may be the large beamwidths used by them.

Thus the measurements of cosmic noise absorption are affected considerably by the sunspot cycle. In any case, the absorption values in middle and low latitude stations are in general low, varying between 1 and 5 dB, whereas the corresponding values in the polar and auroral latitudes are comparatively high.

The present results indicate the existence of a maximum of absorption near about 16 hr I.S.T. However, the maximum values are found to be different for different months. There also exists a prenoon maximum in certain months around 09 hr I.S.T. This prenoon maximum gradually disappeared with the approach of the

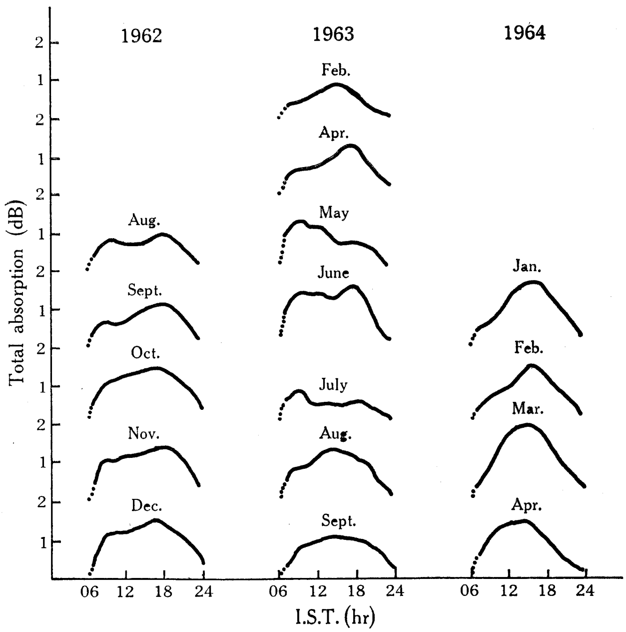

Fig. 2.—Diurnal variation of cosmic noise absorption for each month.

minimum of solar activity and its appearance could not be seen in the records for January–April 1964. In general, the afternoon maximum absorption is found to be greater than the prenoon maximum value, with the exception of May and July 1963, where high absorption is observed in the prenoon period. Following the afternoon maximum the total absorption is found to decrease slowly with time to a negligible value around midnight in all the months during the period of investigation. During spread-F occurrences, which are common for a low latitude station like Bangalore, the absorption has been found to be higher than during normal periods.

(*b*) *Seasonal Variation*

In order to study the seasonal variation of absorption, the year has been divided into two periods depending on the solar zenith angle. The months April–September, for which the solar zenith angle is within $\pm 10°$, have been grouped as summer months and the months October–March, for which the solar zenith angle is greater than 10°, have been grouped as winter months. From the diurnal curves the average absorption for each hour in the above two periods has been determined and the results are shown in Figure 3. From an examination of this figure it can be concluded that there exists a strong seasonal variation showing increased absorption during winter. It can also be seen that there is a pronounced peak of absorption during winter around 16 hr, whereas the absorption during summer is fairly constant between 09 and 19 hr I.S.T.

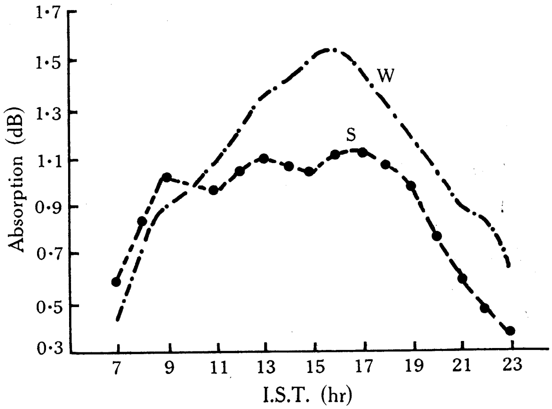

Fig. 3.—Seasonal variation of cosmic noise absorption: W, winter; S, summer.

(c) *Separation of Absorption Contributions due to Various Layers*

The total absorption will naturally consist of contributions from the various layers of the ionosphere. Hence approximate calculations have been made of the contributions to be expected from the different regions of the ionosphere using the electron density and collision frequency profiles that have now become available from rocket and satellite experiments and from incoherent backscatter techniques. For the height range 100–300 km, the ionospheric data (p'–f curves) from Kodaikanal observatory, which is the nearest ionosonde station, have been used. The p'–f profiles were converted to the true height profiles in the usual manner and from these the electron density distribution in the above-mentioned height range was calculated. For the regions below 100 km and above 300 km the data obtained by others have been used. For example, the profile obtained by Herman (1964) for the region below 100 km was used, as his data for 100–110 km coincided with those obtained from the ionograms from Kodaikanal. Similarly, Millman's (1963) curve for the electron density profiles for the region above 300 km, obtained at Bogota using incoherent backscatter techniques, was used to build an electron density profile for the entire height range of 40–800 km. The collision frequency profile obtained by Herman (1964) for heights up to 100 km was extended to 800 km on the model suggested by Mitra and Mathur (1960). Based on this model for electron densities and collision frequencies for a low latitude station, an estimate of ionospheric absorption to be expected from different regions has been calculated. Figure 4 gives the variation of the product of the electron density N and the collision frequency ν with height h. As is well known, the absorption depends upon the value of $\int N\nu \, dh$, which can be calculated for the different regions graphically by computing the area under the curve for each region. From an examination of this figure it can be concluded that there exist three distinct regions of absorption centred at heights of 60, 100, and 350 km, corresponding to D, E, and F regions of the ionosphere respectively. Further, contribution from the E region (10%) is quite comparable with that from the D region (10%). The region below the F_2 layer maximum contributes 32% of the total absorption, whereas the upper ionosphere above the F_2 region accounts for the remaining 48%. This result is very interesting and seems to run contrary to the general belief that the D layer contributes most of the total ionospheric absorption.

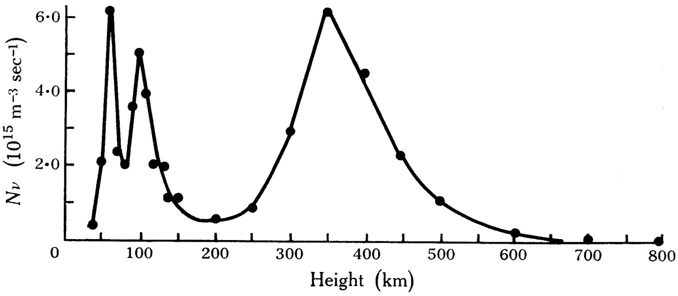

Fig. 4.—Variation of product of electron density N and collision frequency ν with height.

Having thus estimated that the contribution of the F_2 layer and the upper ionosphere to absorption is considerable, the authors have endeavoured to correlate the F_2 layer contribution with the critical frequency $f_0\,F_2$. For this purpose, attention was confined to the results obtained in the late evening hours between 20 hr and midnight. It is reasonable to assume that during this part of the day the only layer present in the ionosphere is the F_2 layer and that the total ionospheric absorption observed at this time is due to this layer only. The logarithm of total ionospheric absorption for different hours of this part of the day was plotted against the logarithm of the monthly mean values of $f_0\,F_2$ for these hours. Figure 5 shows the type of relationship that resulted for typical months; similar relationships exist for the other months. It was established that for all the 16 months the ionospheric absorption during these hours could be represented by the following equation

$$A = b(f_0\,F_2)^2, \tag{1}$$

where A is the absorption (in dB) due to the F_2 region, including the topside ionosphere, b is a constant (in dB/MHz^2), and $f_0\,F_2$ is the critical frequency of the F_2 layer (in MHz). This frequency relation agrees with that obtained by Checcacci and De Giorgio (1964) working on 27·6 MHz at Florence. The value of b has been found to vary from month to month. This is to be expected, as the constant b would depend mainly on the collision frequency, which is likely to change from month to month between narrow limits. The average value of b for the entire period was $0\cdot011\pm0\cdot002$ dB/MHz^2 and compares well with those reported by Checcacci and De Giorgio (1964), namely, $b_{61} = 0\cdot0076$ dB/MHz^2 and $b_{62} = 0\cdot013$ dB/MHz^2.

Assuming that the same relation, as given in equation (1), holds good for the F_2 layer contribution to absorption for the rest of the day also, this contribution was calculated for the remaining hours of the day. The difference between the total observed absorption and the calculated F_2 layer contribution is ascribed to the regions below the F_2 layer.

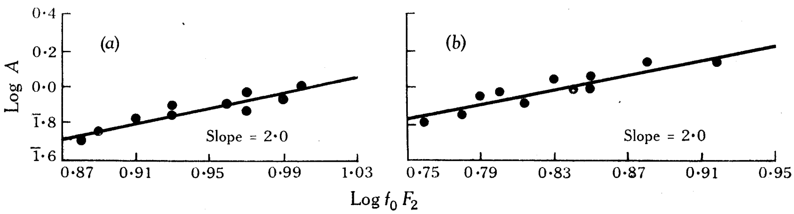

Fig. 5.—Relation between total absorption A at 20·00 I.S.T. and $f_0\ F_2$; (a) September 1962, (b) June 1963.

Following Lusignan (1960), an attempt has been made to correlate this residual absorption (i.e. absorption after removing the F_2 layer contribution from the total absorption) with $f_{\min}$, since $f_{\min}$ can be regarded as an absorption index below the

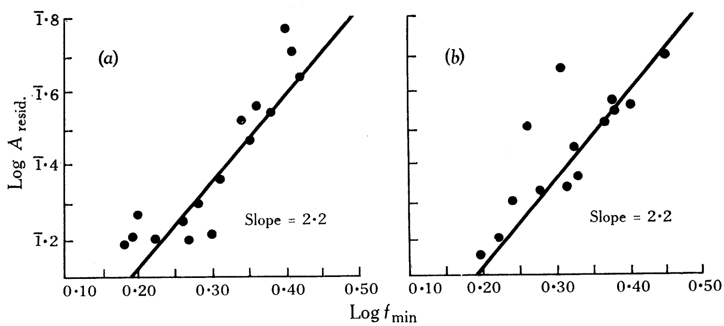

Fig. 6.—Relation between residual absorption $A_{\text{resid.}}$ and $f_{\min}$; (a) winter months average, (b) summer months average.

F region. From Figure 6 it will be seen that this residual absorption can be expressed as a function of $f_{\min}$ to the power of 2·2. Thus the total absorption may be represented by

$$A = b(f_0\,F_2)^2 + c f_{\min}^{2\cdot 2} + d, \tag{2}$$

where A is the total absorption (in dB), b and c are constants (in dB/MHz^2), d is the excess absorption (in dB), $f_{\min}$ is the minimum reflected echo from the F layer observed on the ionosonde records (in MHz), and $f_0\ F_2$ is the critical frequency of the F_2 layer (in MHz). The term d in equation (2) represents that part of the absorption that is not correlated either with $f_0\ F_2$ or $f_{\min}$ and is due to such abnormal phenomena as sporadic-E and spread-F.

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VI. References

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