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Differences Between Al-Absorption Values Measured with Sporadic-E & Normal-E Layer Reflections*

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Ionospheric absorption measurements by A1 method on 2·2 MHz over a period of 14 months at Ahmedabad indicated, in many cases, a distinction between the reflections from the normal-E layer and from totally reflecting low-type sporadic-E layer indicated by significantly lower virtual echo-heights. It appears that the absorption values obtained with these E_s-reflections are generally low by about 35 per cent as compared to the total absorption obtained with normal-E reflections. The above finding supports the view that the totally reflecting E_s acts like a virtually loss-free reflector in contrast to the normal-E layer in which a considerable fraction of the total absorption occurs near the reflection level. A model calculation of absorption gives results consistent with the observed reduction in absorption.

1. Introduction

Besides the regular diurnal, seasonal and solar cycle variations of ionospheric absorption of radio waves, there are—superposed on them—hour-to-honr, day-to-day and month-to-month irregular fluctuations of absorption also. These short-term fluctuations are caused by occasional occurrences of solar flares, sporadic-E ionization, geomagnetic disturbances, and 'meteorological' variability of pressure and temperature of the upper mesosphere and lower thermosphere. Increases in radio wave absorption can be caused by an increase in ionization, and by an increase of the electron-neutral collision frequency which is connected with atmospheric pressure. On the other hand, a sudden change in the *N-h* profile of the D and E regions may cause an instantaneous increase or decrease in absorption depending on the changes produced in the complex refractive index, μ, for a given radio wave frequency, and in the height distribution of the product of electron density and collision frequency. It is known[1,2] that quite a significant amount of absorption takes place in the region where μ decreases appreciably with height within a distance of the order of one wavelength, this being commonly known as 'deviative' absorption. If the reflection level is abruptly shifted to the sharp boundary of a mirror-like reflecting layer situated at the bottom of the 'deviating region', which may be the case with the occurrence of sporadic-E, the total absorption observed under this condition will be reduced to that produced by the lower 'non-deviating' region, where the refractive index is nearly unity.

In this paper, a study of the fluctuations in absorption in relation to the occurrences of sporadic-E layer are reported. It is shown that a reflecting or blanketing low-type E^s at a height of about 94 km causes a reduction in absorption to the extent of 30-35% on certain occasions.

2. Fluctuations in Diurnal Variation of Absorption

Different types of sporadic-E layer occur in the height range 90-120 km. At Ahmedabad low-type, flat-type, cusp-type and high-type E_s are frequently observed, a study of which was earlier reported by Kotadia.[3] On some occasions, the low-type E_s has intense ionization blanketing the E and F1 layers and occasionally a part of the F2 layer. The cusp-type E_s is usually intense and blankets the layers above the normal-E layer upto its top frequency. The flat-type-E^s is embedded within the E layer, and is generally a partially reflecting layer. The frequencies of radio waves used in A1 method of absorption measurement at Ahmedabad are 1·8, 2·2 and 2·5 MHz, and these are normally reflected at levels below the normal-E layer maximum during daytime and from the F region during nighttime in the absence of E^s.

Diurnal variation of absorption observed on 2·2 MHz on some days when low-type blanketing E^s

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occurred is shown in Fig. 1 and is compared with the monthly median variation. The corresponding variations in the heights of reflection are also shown in the same figure. It is clearly seen that the absorption decreases at times when the height of reflection also decreases. The ionograms taken immediately after the absorption record on these days showed occurrences of low-type totally reflecting E_s layer not allowing the radio pulse to traverse in the normal-E layer. There were a few instances of increase in absorption corresponding to the occurrences of E_s, but they were found to be the cases of partially reflecting flat-type E_s within the E layer. In such cases, the reduction in apparent height of reflection is only 2-3 km below that normally observed. The measured absorption in presence of such E_s is not reliable, since the partial E_s reflection and the normal-E reflection are very close to each other and not separated owing to the finite pulse width limitations. In some cases the E_s echo is stronger and in others the normal-E echo is stronger. The echo is so gated that the recorder registers always the peak value of the stronger of the two closeby echoes. Division of the pulse-power at two reflecting levels results in a reduced strength of the principal echo and hence is responsible for increase in absorption.

The extent of reduction in absorption may not be a simple function of the height of the reflecting E_s in individual cases of its occurrence because the absorption is also dependent on the D layer ionization and the gas pressure at a particular time. It may, therefore, so happen that for the same reduction in the height of reflection, the percentage reduction in absorption may be larger than expected if the state of the D layer below is such that it causes less absorption at the time of the occurrence of the reflecting low-type E_s and may be otherwise if the D-layer causes more absorption. So, there will be hour-to-hour and day-to-day fluctuations in the amount of deviation of absorption from the normal even though the difference between the heights of normal-E reflection and the total-E_s reflection remains the same.

3. Time Variation of E_s Occurrence and Reduction in Absorption

The waves of frequencies employed here for measurement of absorption are normally reflected in the E layer for most of the daytime. Among the available observations, the occurrences of E_s which happened to be at heights lower than the normal height of reflection without the E_s and which were at the same time accompanied by a significant decrease in absorption compared to normal, totalled to 172 during the period Dec. 1972-March 1974, majority of them being in Sept.-Oct. period. Data of June-July 1973 were not available. Fig. 2 gives the diurnal

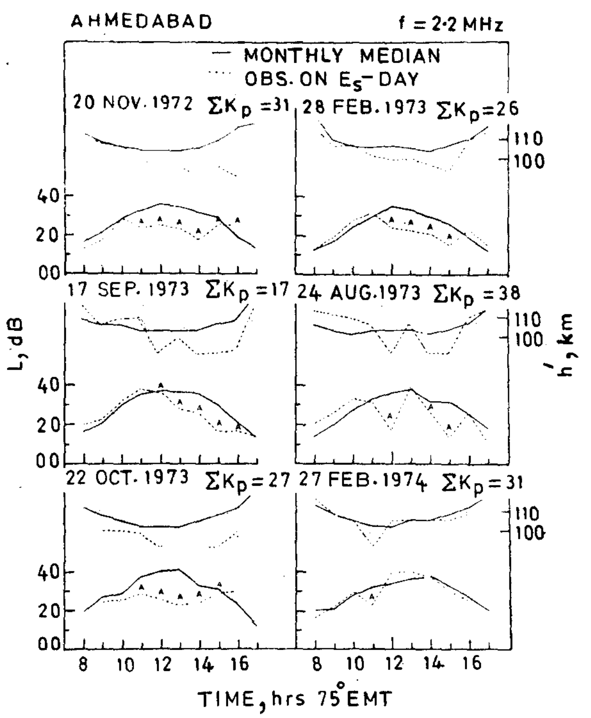

Fig. 1—Diurnal variation of absorption and h' for E_s reflection compared with that of monthly median variation (The letter A inside the figure indicates the presence of blanketing low-type E_s)

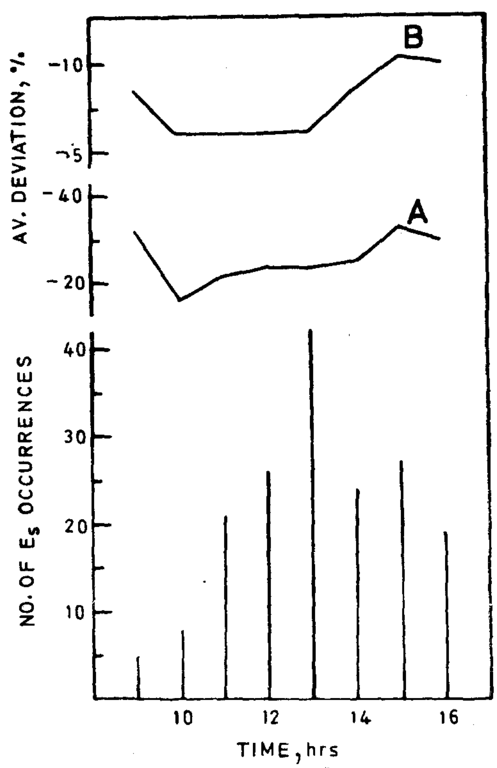

Fig. 2—Diurnal variation of deviation in absorption [curve (A)] and h' [curve (B)] shown with distribution of E_s-occurrences

distribution of the occurrences of reflecting type E_s and shows frequent occurrences of E_s in the interval 1100-1500 hrs. The values of average diurnal variation of decrease in absorption and decrease in height of reflection are high near sunrise and sunset times. However, the average reduction in L and h' at these times may not be much relied upon as the occurrences of E_s are only a few. But one thing is clear that the reduction in L is due to the lowering of the height of reflection below the deviating region. The diurnal variation of this effect on L depends on the normal diurnal variation in the height of reflection in the E region, the height of E^s at a particular hour and the diurnal variation of absorption in the D region. Based on these factors, it is expected that the reduction in absorption due to total reflection from E_s would be minimum around noon, and this is really so as can be noticed from Fig. 2.

4. Frequency Distribution of Es Occurrence for Different Ranges of Reduction in Height of Reflection and Absorption

Taking all the instances of the reflecting low-type E_s that occurred at the time of absorption measurements, distributions of the E_s occurrences for specified ranges of reduction in height of reflection and percentage reduction in absorption as compared to that observed for normal-E reflection are shown in Fig. 3 (a,b). It is seen that the probability of the occurrences of E_s that cause 30-35% reduction in absorption and 6-8% reduction in the virtual height of reflection is largest. There are other less frequent instances for smaller and greater reductions of absorption, but generally the greater reduction in absorption is associated with more reduction in height of reflection and likewise for smaller reduction. The two distributions need not be identical because it very much depends on the way of specifying the ranges and we do not always have the same reductions in L for a specified range in h' under different ionospheric conditions. It may, however, be concluded that a maximum of 30-35% reduction in absorption would result when the reflection takes place at a height 7-9% lower than normal height (h') in the absence of E_s.

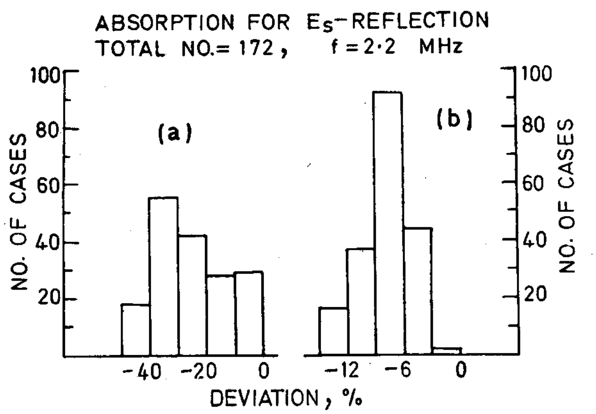

Fig. 3—Distribution of occurrences of E_s for different ranges of reduction in (a) absorption and (b) virtual height of reflection

5. Model Estimation of the E_s Effect on Absorption

Since most of the E_s occurrences including some producing 30-35% reduction in absorption are contained in the interval 1100-1500 hrs although the average reduction for the individual hours is about 25%, we may attempt to estimate the absorption suffered by the wave in its passage up to a certain height using a certain model profile for electron density and the collision frequency for near-noon conditions, say at solar zenith angle $\chi = 10°$. Here, the N-h and ν-h profile models given by Gnanalingam and Kane[4] are adopted to calculate absorption according to the expression given by Whitehead[1] for the value of k, the absorption per unit distance, viz.

$$\frac{\nu}{2c}\frac{X(1+2Q_2\cot^2\theta)}{(1+Q_1Y_L)^2}\left\{1-\frac{X}{1+Q_1Y_L}\right\}^{-1/2}$$

for an approximation condition $(1-X) \gg Z$ where k is in nepers/metre,

$$X=\frac{f_N^2}{f^2}=\frac{Ne^2}{\pi m_e f^2},\ Y_T=\frac{f_H}{f}\sin\theta,\ Y_L=\frac{f_H}{f}\cos\theta$$

$$Z=\frac{\nu}{\omega}$$

$$Q_1=(\sqrt{1+m_e}-m)$$

$$Q_2=\frac{m^2(\sqrt{1+m^2}-m)}{\sqrt{1+m^2}}$$

$$m=\frac{Y_T^2}{2Y_L}=\tfrac{1}{2}Y_T\tan\theta$$

where ν is electron collision frequency, f_N is plasma frequency, m_e is mass of electron, $\omega=2\pi f$ and θ is the angle between the direction of wave propagation and magnetic field; f_H for Ahmedabad is taken as 1·2 MHz and, the operating radio frequency f is 2·2MHz. The height range considered for calculation of absorption is 60 km up to the true height of reflection known from the N-h profile where N becomes equal to $1{\cdot}24\times10^{10}\times(2{\cdot}2)^2$ electrons/m^3. This true height of reflection in the absence of the lower E_s is found to be 96·7 km from the assumed profile.

The total absorption is found by calculating absorption in ionization strips of 1 km from 60 km to 94 km, strips of 200m from 94 km to 96 km and strips of 100 m in the last upper strip and then adding up all these absorption values. The N-h and ν-h profiles adopted in our calculations gave total absorption satisfactorily agreeing with that observed at $\chi = 10°$.

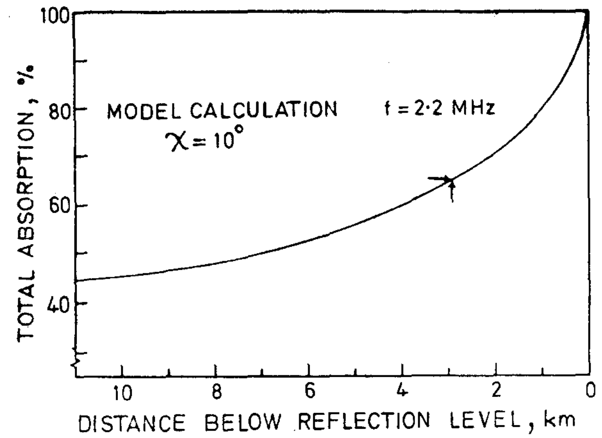

Fig.4—Calculation of total absorption up to different heights using $N(h)$ and $\nu(h)$ models given by Gnanalingam and Kane[4] and Whitehead's approximate formula[1] (The arrows indicate total absorption obtained with the blanketing low-type Es)

The absorption of the wave up to a certain height can be expressed in per cent of the total absorption suffered up to the height of reflection. Fig. 4 shows the results of this computation giving variation of absorption with true height of the wave-passage. A horizontal arrow mark indicates the absorption of 65% of the total and this corresponds to a true height of 93·7 km. It is interesting to note that the absorption measured by the reflection from low-type E_s known to occur at a real height of about 94 km is also 65% of that observed from normal-E reflection. Thus a reduction of 35% in absorption when the true height of reflection is reduced by 3 km accounts approximately for the deviative absorption occurring in that 3 km stretch of the normal-E from its bottom. Earlier, a reduction of about 25% in absorption due to reflection from the low-type E_s was reported by Purkait and Datta.[5]

6. Discussion and Conclusion

One hundred and seventy two instances of blanketing low-type E_s were recorded during the period Dec. 1972-Mar. 1974. A large number among these occurred in the interval 1100-1500 hrs. The occurrence of such E_s is always accompanied by a significant reduction in absorption. This effect has a diurnal variation with a minimum around noon and maxima near sunrise and sunset times. The large reduction in height of reflection in the morning and evening, less deviative absorption in the normal-E region and more non-deviative absorption in the D region towards noon explains the observed diurnal variation of the reduction in absorption due to the total reflection from the low-type E_s.

The distribution of the occurrences of E_s for different ranges of reduction in absorption and virtual height suggests a probability of maximum reduction of about 35% in absorption corresponding to a decrease of 9% in the virtual height of reflection below that observed for reflection from the normal-E layer. A model computation yields a 35% reduction in absorption corresponding to a decrease of 3 km in the real height of reflection, that of normal E-reflection being taken as 96·7 km at 2·2 MHz, which corresponds to a virtual height of 105 km. The true height of most frequently occurring low-type E_s is 93·7 km corresponding to a virtual height of 96 km. The difference between the true height and the virtual height decreases as h' decreases, and so the low value (3 km) of decrease in the real height of reflection due to E_s is understandable. It is interesting to note here that the strongly reflecting low-type E_s is known to occur at a height of about 93 km as also found from the model computation for a decrease of 35% reduction in absorption. Such a sporadic E layer is attributed to metallic ions (Goldberg).[6] The $N(h)$ and $\nu(h)$ models and the approximate Whitehead's formula adopted for computation of absorption at 2·2 MHz yield results in good agreement with the observed absorption within the limits of experimental error.

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