Absorption of HF radiowave (20 MHz) in F-region of the ionosphere

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By considering the theoretical work of S Chapman and C G Little [J Atmos & Terr Phys (GB), 10 (1957) 20] the non-deviative absorption for 20 MHz radio frequency in F-region of the ionosphere has been calculated using the electron-neutral collision frequency obtained by S N Ghosh and P K Sarkar [Indian J Radio & Space Phys, 7 (1978) 46]. The calculated electron-neutral and electron-ion collision frequencies due to different sets of observed electron density and temperature profiles in the altitude range 200-400 km vary from 4.6 x 10^3 to 1.0 x 10^2 s^{-1} and from 8.3 x 10^2 to 0.91 x 10^2 s^{-1}, respectively. The total absorption for 20 MHz radiowave in the same altitude range calculated for the same electron density and temperature profiles vary between 0.35 and 0.84 dB. These absorptions agree with cosmic radio noise absorption (i.e. 0.25-0.94 dB) for 20 MHz in F-region measured during January-October 1964 at Delhi by S B S S Sarma et al. [Indian J Pure &Appl Phys, 8 (1970) 529].

1 Introduction

Effective collision frequencies have been experimentally determined from radiowave absorption with respect to group heights for frequencies reflected from the F-region by several investigators. It is seen that the effective collision frequencies obtained from absorption experiments (Fig. 12 of Ref. 1) are consistently larger than the theoretical estimates of collision frequency even under the limiting assumption of $T_e = T_N$ (the neutral gas temperature). There is also a sizeable contribution of F-region absorption even during minimum solar activity in riometer observations at low latitudes. This sizeable contribution comes from a region where the electron temperature is higher than the neutral gas temperature so that the F-region absorption, when properly separated, can provide information on the electron temperature and its variation with altitude. The electron temperatures calculated by riometer method seem to be inconsistent with the currently measured values. Saha and Venkatachari have calculated F-region absorption which is inconsistent with the observed absorption by cosmic radio noise method. The observed value is consistent with their theoretical value of absorption only when the effect of magnetic field is taken into account, but gives very low value of electron temperature (600K) at F-region (Fig. 4 of Ref. 2). Also, the calculated absorption with $T_e = 2500$K gives much lower absorption for any $f_0F2$ value. This discrepancy between the apparently high values of F-region collision frequencies obtained with absorption technique and those expected from known values of electron temperature can be resolved by considering the electron-neutral collision frequency obtained by Ghosh and Sarkar. In F-region, the electron neutral collisions are wholly due to electron-atomic oxygen collision and slightly by electron-N_2 collision. The effective collision frequency is the sum of electron-atomic oxygen and electron-ion collision frequencies.

By considering the theoretical work of Chapman and Little, the non-deviative absorption of HF radiowave (20 MHz) in F-region of the ionosphere (200-400 km) has been calculated with the inclusion of electron-neutral collision frequency in the effective collision frequency.

2 Working formula

The non-deviative absorption of the ordinary component of radiowaves of high frequency (say, 3-30 MHz) propagating through the ionosphere is represented by Chapman and Little as

$$A = 1.17 \times 10^{-14} \int \frac{n_e \nu}{f} dh \quad \ldots (1)$$
where,

\[ A \] Absorption in dB
\[ \nu = \nu_e + \nu_e_i \] Effective collision frequency
\[ f \] Frequency of radiowaves in MHz
\[ dh \] Element of path along the vertical

The electron-ion collision frequency, \( \nu_e_i \), adopted from Banks\(^8\) or Majumdar\(^9\) is given by

\[ \nu_e_i = 54 n_i T_e^{-3/2} \text{s}^{-1} \] \hspace{1cm} (2)

where \( n_i \) is the density of ion and \( T_e \) the electron temperature.

In F-region, electron-neutral collision frequency, \( \nu_e-N_2 \), is wholly contributed by \( \nu_e-O \) and slightly by \( \nu_e-N_2 \). The value of \( \nu_e-O \) is calculated from the method of Ghosh and Sarkar\(^4\) by considering the atomic oxygen cross-section of Mitra et al.\(^10\) and is given by

\[ \nu_e-O = 8.28 \times 10^5 n(O) \sigma(O) T_e^{-1/2} \text{s}^{-1} \] \hspace{1cm} (3)

where,

\[ n(O) \] Atomic oxygen density
\[ \sigma(O) \] Atomic oxygen cross-section with low energy electrons

The experimental cross-section of \( N_2 \) after Anderson Goldstein\(^11\) which is equal to \( 1.7 \times 10^{-15} \text{cm}^2 \) for thermal electron energies has been adopted to calculate the \( e-N_2 \) collision frequency and is given by

\[ \nu_e-N_2 = 1.41 \times 10^{-9} n(N_2) T_e^{1/2} \text{s}^{-1} \] \hspace{1cm} (4)

Eq. (1) can be expressed for \( f = 20 \text{ MHz} \) as

\[ A = 5.85 \times 10^{-11} \left[ n_e \left( \nu_e-O + \nu_e-N_2 + \nu_e_i \right) \right] \]
\[ \times \frac{h_1 + h_2}{2} \text{ dB} \] \hspace{1cm} (5)

The integration \( \int_{h_i}^{h_2} (n_e \nu) dh \) is carried out for 20 km interval in the altitude range 200-400 km.

3 Results and discussion

Absorption for 20 MHz are calculated from Eq. (5) in the altitude range 200-400 km. The values of \( \nu_e-i, \nu_e-O \) and \( \nu_e-N_2 \) (up to 300 km) are calculated from Eqs (2), (3) and (4), respectively. The electron temperature and electron density profiles are considered from the following.

(i) Thomson scatter radar results are 1425-2150 K and 3.5-1.1 \times 10^5 \text{ cm}^{-3} at 200-400 km, respectively on Jan. 1965 at 1000-1500 hrs EST at Millstone Hill\(^12\).

(ii) Thomson scatter radar results are 1037.5-2032.5 K and 3.27-1.55 \times 10^5 \text{ cm}^{-3} at 200-400 km, respectively on 6-8 Apr. 1965 at 1000-1500 EST at Millstone Hill\(^12\).
4 Conclusion

The values of collision frequencies given in Fig. 2 when considered in Eq. (5), the calculated absorptions and electron temperatures agree with the experimentally measured values in F-region. The discrepancy between the observed (riometer method, Ref. 1) and calculated (Ref. 2) values of collision frequency and electron temperature in F-region of the ionosphere is thus removed. The calculated values of absorption in the altitude range 200-400 km lie between 0.35 dB and 0.84 dB. This agrees with the measured values 0.25-0.94 dB (Ref. 3) which shows that the major contribution towards total absorption comes from the F-region.

References

11 Anderson J M & Goldstein L, Phys Rev (USA), 102 (1956) 388.