THE F_2 COMPONENT OF COSMIC RADIO NOISE ABSORPTION

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Summary

The attenuation of cosmic radio waves expected in the F region is calculated. It is shown that by using an F-region model obtained from electron backscatter measurements the attenuation obtained agrees well with observation. The amount of attenuation is generally less than $0 \cdot 2$ dB, providing the wave frequency is greater than twice f_0F_2 for wave frequencies less than 10 Mc/s.

I. Introduction

Early observations of cosmic radio noise at $18 \cdot 3$ Mc/s by Mitra and Shain (1953) have shown that the ionosphere produces noticeable attenuation even when the critical penetration frequency f_0F_2 is much less than the observing frequency. By carefully comparing the variation of the attenuation with the measured properties of the ionosphere they were able to distinguish three separate attenuation components; one due to the D region, one which varied with f_0F_2, and a remaining "extra component" which was not associated either with the D region or with f_0F_2. Subsequent investigations by Lusignan (1960) confirmed this general analysis.

As well as discovering the so far unexplained extra component of absorption, Mitra and Shain observed that the F_2 component varied more strongly with f_0F_2 and was considerably greater than would be expected theoretically with a Chapman layer. This latter discrepancy, in particular, appeared to throw doubt on the possibility of profitably observing cosmic radio noise below the ionosphere at frequencies much less than 18 Mc/s. However, subsequent observations even at $2 \cdot 13$ Mc/s (Reber and Ellis 1956) did not appear to be unduly hindered by ionospheric absorption.

Here we re-examine theoretically the question of the F_2 absorption, particularly in the light of recent measurements of the $N(h)$ profile of the F region and above.

II. Model Ionosphere

We choose a model F region based on the free electron backscatter observations of Pineo and Hynek (1962) and of Bowles (1963). These showed that the $N(h)$ profile remains almost constant in shape during the night hours although the maximum density changes. In addition, the electron density falls slowly with height above the F region. Figure 1 shows samples of the profiles used in the present calculations. The parts of the curves below 600 km were taken from the results of Pineo and Hynek, since their observations were all made on the same night. The profiles for the height interval between 600 and 4000 km were fitted to the tail of the F_2 profiles and made similar in shape to the profiles of Bowles for the same height range (see also Warren 1963).

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The density of the neutral atoms at 300 km was assumed to be 2×10^9 cm^{-3} (after Gliddon and Kendall 1962) and the entire region was assumed to be isothermal. The backscatter observations of Pineo and Hynek and of Bowles support this latter assumption. In addition, following Gliddon and Kendall, we assume equality of electron and ion temperature and equality of the electron and ion densities. A dipole geomagnetic field is assumed with magnetic latitude of 45°.

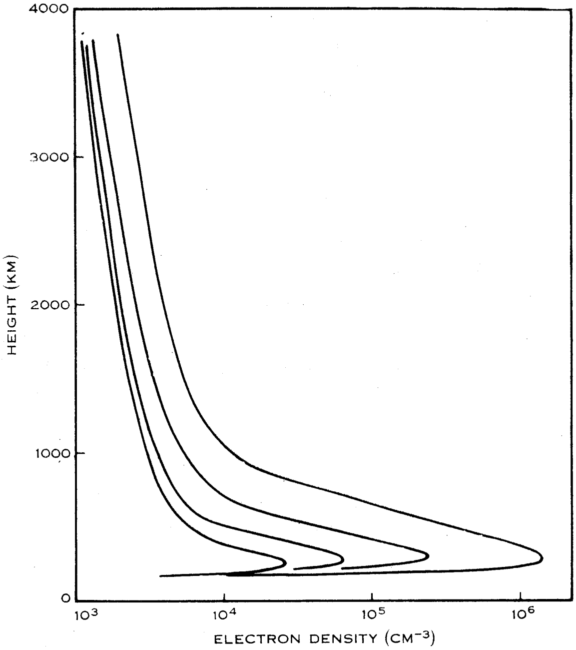

Fig. 1.—Assumed $N(h)$ profiles for the F region and above.

III. Discussion

The absorption of radio waves by an ionized medium is given by $\exp(-\int K\,\mathrm{d}S)$, where

$$K \sim \frac{\nu}{2cn}\frac{f_0^2}{(f \pm f_H)^2}, \qquad n = \text{refractive index}, \tag{1}$$

and the collision frequency

$$\begin{aligned}\nu &= \nu_{\mathrm{ea}} + \nu_{\mathrm{ei}} \\ &= 1 \cdot 8 \times 10^{-8}(T/300)^{1/3}N_{\mathrm{a}} + 6 \cdot 1 \times 10^{-3}(T/300)^{-3/2}N_{\mathrm{i}}\end{aligned} \tag{2}$$

(Cowling 1945).

ν_{ea} and ν_{ei} are the collision frequencies for collisions between electrons and neutral atoms and electrons and ions respectively. We note that, if we put $\nu_{\mathrm{ea}} \ll \nu_{\mathrm{ei}}$, $N_{\mathrm{e}} \propto N_{\mathrm{i}}$, $n \sim 1$, and T constant,

$$K \propto f_0^4.$$

The attenuation might therefore be expected in general to decrease very rapidly with f_0 above the F region where these restrictions are allowable. Also, if in the F region, for high values of f_0F_2, $\nu_{ei} \gg \nu_{ea}$, then

$$K \propto T^{-3/2}$$

for a constant value of f_0.

The computed absorption curves for wave frequencies of 1·5, 2·3, 4·7, and 18·3 Mc/s, with the model of Figure 1 and using equations (1) and (2), are shown in Figure 2. Also shown are the experimental results of Mitra and Shain (1953) at 18·3 Mc/s and more recent observations at 4·7 Mc/s by Ellis and Green (1963). It is seen that the theoretical curves fit the observations well and there does not appear to be any discrepancy of the type discussed by Mitra and Shain. The increased attenuation they noted at night at 18·3 Mc/s can be explained by the decreased F-region temperature at night.

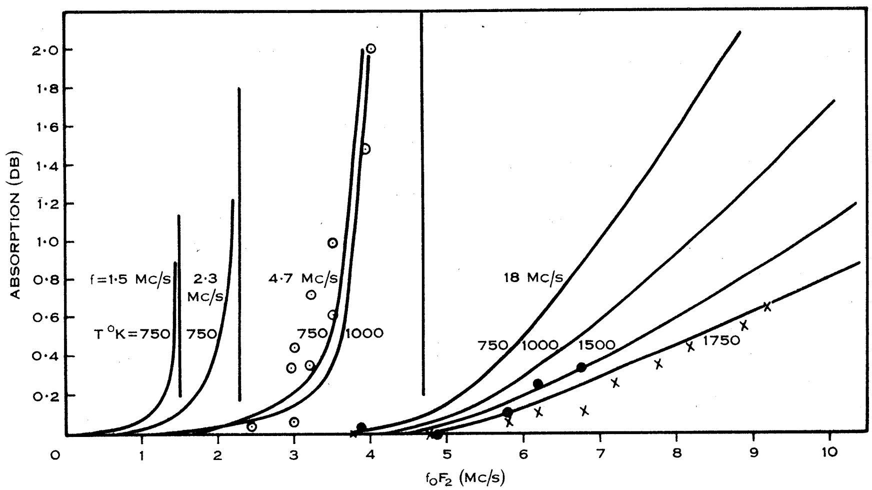

Fig. 2.—Calculated attenuation due to the F region for wave frequencies of 1·5, 2·3, 4·7, and 18·3 Mc/s. ●, ×: day and night observations of the F component of absorption at 18·3 Mc/s (Mitra and Shain 1963). ○: night observations of absorption at 4·7 Mc/s (Ellis and Green 1963).

As the observing frequency f is decreased, we note that a given attenuation occurs for a relatively higher value of f_0F_2. For observations at 4·7 Mc/s, for example, the attenuation is 0·2 dB when $f_0F_2 = 0 \cdot 66f$, whereas at 18·3 Mc/s the corresponding fraction is $f_0F_2 = 0 \cdot 3f$.

This effect is partly caused by the lower electron-ion collision frequencies obtained for small values of f_0F_2. In addition, the extraordinary mode is highly attenuated for wave frequencies less than $\sim$2·5 Mc/s because of cyclotron resonance centred at about 1·5 Mc/s. In computing the attenuation for 2·3 and 1·5 Mc/s therefore only the ordinary mode was considered. This has the effect of making the attenuation appear less than at the corresponding ratios of f_0F_2/f for the higher frequencies. Actually 3 dB has to be added to all values for 1·5 and 2·3 Mc/s.

It would appear that the F_2 component of cosmic noise absorption is explained without difficulty in terms of the expected properties of the F region. The "extra" component referred to earlier remains somewhat of a mystery. This analysis shows that no extra attenuation can be produced in an extended region above F_2, as suggested by Mitra and Shain. In the calculations illustrated in Figure 2 only an insignificant proportion of the total attenuation occurred above the F region whatever the wave frequency.

It seems likely therefore that the properties of the F region differ from those of the assumed model in a way which would not be revealed easily by existing observational techniques and which would not affect the F_2 component of absorption. The most obvious necessary modification to the model would be the inclusion of irregularities in the electron distribution.

Weak random irregularities would not suffice since they would merely redistribute the radiation but would not produce an overall attenuation. However, substantial attenuation might be produced by irregularities aligned along the magnetic field and acting as wave guides, as suggested by Pitteway (1962).

IV. References

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