SUPPOSITION OF THE EXISTENCE OF AN IONIZED LAYER UNDER E-LAYER

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§ 1. Introduction.

The lowest frequency of the receivable wave which is reflected from E-layer, that is f_{Emin}, varies regularly with the local time. According to the statistical study about the data of 27 months (from December, 1946 to February, 1949), f_{Emin} reaches to its maximum value at noon and the change of the values is symmetrical before and after the noon. Considering that the second kind of attenuation in E-layer is comparatively small for such a low frequency and the absorption of radio wave is mainly due to the first kind of attenuation in the absorbing layer which exists in a lower region than E-layer, the diurnal variation of f_{Emin} gives some suggestive informations concerning such a layer. In this paper, the possibility of the existence of such a layer is discussed under some assumptions.

§ 2. The Observed Results.

In Tokyo, the hourly values of f_{Emin} have been observed at the Electrical Communication Laboratory, the Ministry of Communications. For each season and throughout the year, the hourly mean values of f_{Emin} taken from the data of the recent 27 months are given in Table 1 and the diurnal variation is shown in Fig. 1 and 2. It is noticeable that the maximum value occurs half or an hour after the noon and the mode of this

Table 1.
The Hourly Mean Values of f_{Emin} and $A \cos^{\frac{3}{4}} \chi$

Season	J.S.T.	8	9	10	11	12	13	14	15	16	17
Winter	Observ.	1.63	1.71	1.78	1.94	2.00	2.04	1.84	1.75	1.65	1.54
	$A \cos^{\frac{3}{4}} \chi$			1.81	2.04	2.11	2.04	1.81	1.43		
Equinox	Observ.	1.74	1.92	2.25	2.48	2.61	2.61	2.42	2.12	1.87	1.63
	$A \cos^{\frac{3}{4}} \chi$		2.04	2.37	2.57	2.64	2.57	2.37	2.04	1.58	
Summer	Observ.	1.87	2.28	2.88	3.23	3.53	3.62	3.33	2.70	2.00	1.82
	$A \cos^{\frac{3}{4}} \chi$		2.73	3.07	3.26	3.33	3.26	3.07	2.73	2.28	
Annual Mean	Observ.	1.74	1.96	2.29	2.53	2.69	2.72	2.50	2.17	1.72	1.61
	$A \cos^{\frac{3}{4}} \chi$		2.07	2.42	2.62	2.70	2.62	2.42	2.07	1.59	

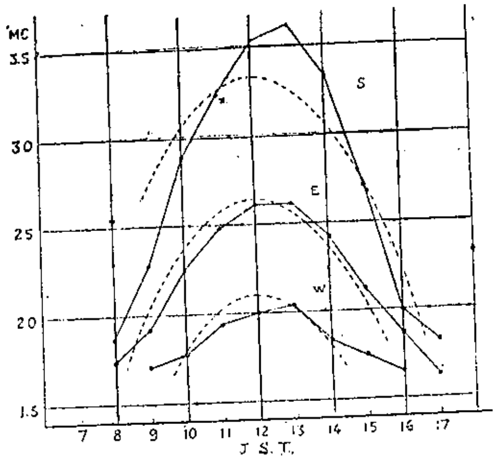

Fig. 1 The Diurnal Variation of f_{Emin} for Each Season.

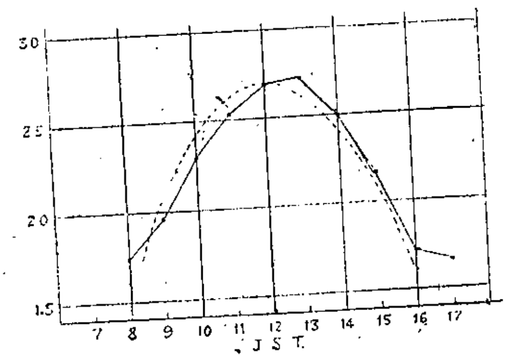

Fig. 2 The Diurnal Variation of f_{Emin} on the Average throughout a Year.

change is symmetrical before and after the noon. This variation is similar remarkably to that of the penetrating frequency of E-layer which is regarded as a typical single layer.

§ 3. The Absorption of Radio Wave.

In general, the absorption-coefficient is given by

$$\gamma=\frac{2\pi e^2 N}{mc\mu}\cdot\frac{\nu}{p^2+\nu^2}, \qquad \cdots\cdots(1)$$

where

$$\mu^2=1-\frac{4\pi e^2 N}{m(p^2+\nu^2)},$$

and m, e, and N denote the mass, the charge, and the density of the electron respectively, ν is the collisional frequency of the electron to neutral molecules or atoms, and p is the angular frequency of the electromagnetic wave. If the second kind of attenuation in E-layer can be neglected for such a low frequency and the total absorption of radio wave is due mainly to the first kind of attenuation in the lower layer which is supposed to be ionized by the similar solar radiation to the Dellinger effect (1), the whole attenuation is given by the following equation (2):

$$\Gamma=k\frac{1}{p^2}\int N\nu dh, \qquad \cdots\cdots(2)$$

where k is a constant and the integration must be exerted from the lower boundary to the upper limit of the layer. For simplicity of the calculation, suppose the ionization-density of this layer is given by the Chapman's formula (3):

$$N=N_0 \exp\left\{\frac{1-z-e^{-z}\sec\chi}{2}\right\}, \cdots(3)$$

where

$$z=\frac{h-h_0}{H},$$

and χ is the solar zenith distance, N_0 is the maximum density when $\chi=0$, h is the height above sea level, h_0 the height where the density is N_0, and H is the scale-height. And it is reasonably assumed that ν is given by

$$\nu=\nu_0 e^{-z}, \qquad \cdots\cdots(4)$$

where ν_0 is ν at the height of h_0.

Then,

$$\Gamma=k\frac{HN_0\nu_0}{p^2}X,$$

$$X=\int_{-\infty}^{+\infty}\exp\left\{\frac{1-3z-e^{-z}\sec\chi}{2}\right\}dz.$$

Putting

$$e^{-z}=t,$$

$$X=e^{\frac{1}{2}}\int_0^\infty t^{\frac{1}{2}}e^{\frac{-t\sec\chi}{2}}dt$$

$$=e^{\frac{1}{2}}\frac{\Gamma\left(\frac{3}{2}\right)}{\left(\frac{\sec\chi}{2}\right)^{\frac{3}{2}}}$$

$$=e^{\frac{1}{2}}\frac{\sqrt{2\pi}}{(\sec\chi)^{\frac{3}{2}}},$$

where $\Gamma\left(\frac{3}{2}\right)$ is the gamma-function. Then

$$\Gamma = \frac{HN_0\nu_0}{p^2}\frac{\sqrt{2\pi e}}{(\sec\chi)^{\frac{3}{2}}}. \quad \cdots\cdots(5)$$

Therefore, the whole attenuation can be expressed as the function of p and χ.

If the magnitude of the attenuation reaches some value, the intensity of the echo is insufficient for the reception. And at any time, it is difficult for the receiving set to feel the echo of the lower frequency. Considered that the transmitting power and the receiving sensibility are kept constant all day long on the average for such a long period, the magnitude of the attenuation under the precarious condition that the receiver feels barely the weakest echo of the low frequency, that is f_{Emin}, can be regarded as the constant value. Then, the relation between f_{Emin} and the zenith angle (χ) of the sun is driven from (5) as follows:

$$f_{Emin} = A\cos^{\frac{3}{4}}\chi, \quad \cdots\cdots(6)$$

where A is a constant.

The observed values satisfy this relation. But the time when f_{Emin} becomes to the maximum value is slightly lag from the noon. This suggests the necessity of the consideration for the apparent recombination of the electrons in the layer. The value of constant A in the equation (6) is 3.26 which is calculated by means of the least squares. The values of $3.26\cos^{\frac{3}{4}}\chi$ are shown in Table 1 and by the dotted line in Fig. 1.

§ 4. Discussion.

If the distribution of electrons in this region shows that of the Chapman's theory, we have

$$n = N_0\cos^{\frac{1}{2}}\chi, \quad \cdots\cdots(7)$$

where n is the maximum electron-density, and N_0 is the value of n when $\chi=0$. Then, by (6) and (7),

$$(f_{Emin})^{\frac{2}{3}} = Cn, \quad \cdots\cdots(8)$$

where C is a constant. On the other hand, supposing only the recombination-process, we have

$$\frac{dn}{dt} = q_0\cos\chi - \alpha n^2, \quad \cdots\cdots(9)$$

where q_0 is the rate of ion-production when $\chi=0$ and α is the apparent recombination-coefficient.

Let

$$m = (f_{Emin})^{\frac{2}{3}} \text{ and } n = am, \quad \cdots\cdots(10)$$

where $a(=1/C)$ is constant value, so that

$$\frac{dm}{dt} = \frac{q_0}{a}\cos\chi - a\alpha m^2. \quad \cdots\cdots(11)$$

The value of dm/dt and m are obtained from the data, by means of the numerical differentiation and from (10), and are shown in Table 2.

Table 2.
The Hourly Values of m and dm/dt.

J.S.T.	9	10	11	12	13	14	15	16
dm/dt	0.15	0.15	0.10	0.06	-0.04	-0.14	-0.18	-0.14
Obs. m	1.55	1.72	1.8[illegible]	1.91	1.93	1.83	1.67	1.50
Cal. m	1.55	1.74	1.86	1.91	1.90	1.81	1.67	1.46

Using the observed values, the values of q/a and $a\alpha$ are calculated by means of the least squares, and obtained as 4.69/hour and 0.99/hour respectively, and the value of αq_0 is the order of 8.7×10^{-8}/sec that is acceptable for our physical conception. According to these values, the most probable m and dm/dt are calculated by means of the numerical integration as shown in Table

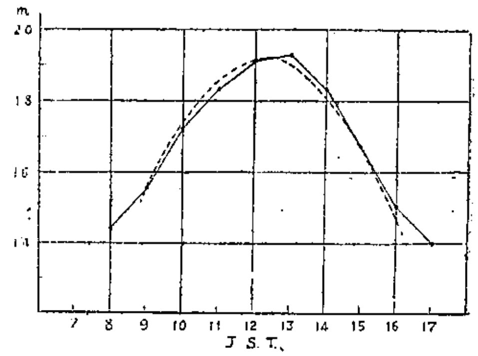

Fig. 3. The Variation of m.

2 and Fig. 3. It is remarkable that the observational curve agrees completely with the calculated curve within the error of the calculations.

§ 5. Conclusion.

Though there may be some uncertainty with regard to the neglection of the attenuation in E-layer, the calculated values obtained under some assumptions agree very closely with the observed values. This result probably suggests that there exists an absorbing layer, which is ionized by the solar radiation, in the lower region than E-layer.

§ 6. Acknowledgment.

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