level. Against the first hypothesis, both observations and calculations show that the lower boundary of the *E* layer must be extremely sharp[3]. From such a boundary all frequencies below the critical penetration frequency will be copiously reflected, while all those above will penetrate the boundary. Observations made by us, however, show that during daytime there is a frequency band above and below the limits of which no reflection is obtained from the *E* layer. The limits of the frequency band vary with the hour of the day. Fig. 1 depicts typical limits on a summer day at Calcutta.

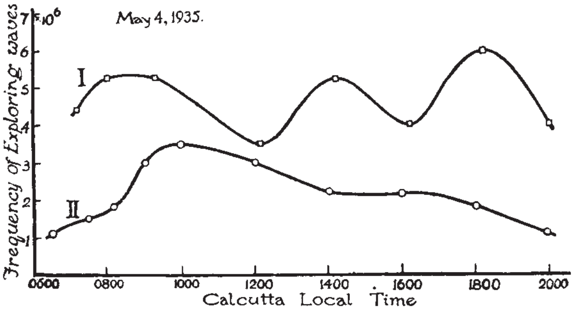

FIG. 1. Curve I gives the penetration frequencies of the *E* layer for various hours of the day. Curve II gives the frequencies for which echoes from the *E* layer first appear from the side of long waves. The vertical distance between the two curves for any hour of the day gives the range of frequency for which echoes are obtained from the *E* layer only.

The hypothesis of a diffuse *D* layer at low height, where collision frequency is very great, offers an easy explanation of these phenomena. This layer will absorb long waves strongly, preventing their reflection due to the diffuse boundary, and will only allow waves of lengths below a certain limit to penetrate it. These latter waves will either be reflected from or will penetrate the *E* layer. In short, the *E* layer with its sharp boundary will reflect all frequencies below a certain limit and the *D* layer with its diffuse boundary absorb all frequencies below another lower limit. The sharp boundary of the *E* layer cannot cause the disappearance of frequencies lower than the critical penetration frequency as shown in Fig. 1. The hypothesis of a diffuse *E* layer boundary causing absorption is untenable because the virtual height of the *E* layer as measured by us for a number of frequencies in the frequency band of Fig. 1 has been found to be practically constant.

On very rare occasions when the lower boundary of the *D* layer becomes extremely sharp, it is able to reflect waves. Such were the occasions on April 2, 3 and 5 between the hours 15.00 and 17.00, when we were able to detect the echoes as reported in the beginning of the note.

There are other arguments in favour of the existence of the *D* region. Without the intervention of such a region, the virtual height of the *E* layer ought to rise gradually with the setting of the sun. Observations show, however, that the height has a tendency to decrease with the close of the day. This is easily explained as due to the disappearance of the *D* layer, which by its presence during the day increases the virtual path of the wave. Again, Fig. 1 shows that Curve I, which is a graph of the penetration frequencies of the *E* layer, has pronounced hourly variations. This feature of the curve is present almost every day during this part of the year. Curve II, which is a graph of the frequencies for which echoes begin to appear from the *E* layer, has no such pronounced hourly variations, but gradually rises and falls with the progress of the day. There being scarcely any correlation between the two curves, it follows that the agency responsible for Curve I must be different from that for Curve II. This other agency, according to our hypothesis, is the absorbing layer at a virtual height of 55 km.

It is noteworthy that the region where the absorbing layer has been detected by us, is also, according to many authorities, the region of the ozonosphere[4]. It is not unlikely that the ionisation in this region is connected with the formation of ozone, as suggested by Chapman[5].

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Propagation of Radio Waves over a Plane Earth

THE purpose of this letter is to point out an error in sign in Prof. A. Sommerfeld's original paper (1909) on the attenuation of radio waves[1]. This error in sign has recently been reflected in Bruno Rolf's graphs[2] of the Sommerfeld formula, predicting dips to zero in the field intensity at finite distances from a radio transmitter and other anomalous phenomena. This error in sign has been corrected in Prof. Sommerfeld's 1926 papers[3] and also does not occur in the derivation by B. van der Pol and K. F. Niessen[4]. In this latter paper an exact expression is given for the potential of a vertical infinitesimal dipole (equation 21). After expanding this expression, I found that most of the terms are negligibly small at moderately low frequencies for distances from the source greater than a wave-length, giving for the potential function of a vertical dipole over a plane earth:

$$\Pi\,(r, 0) = \frac{e^{ik_1 r}}{r}\left[1 - 2\sqrt{p}\; e^{-p}\int_{i\infty}^{\sqrt{p}} e^{w^2}dw\right]$$

$$\text{where } p = ik_1 r\left[\,1 - \left\{1 + \left(\frac{k_1}{k_2}\right)^2\right\}^{-1/2}\right] \equiv p_0 e^{ib} \quad (1)$$

$$\text{and } k_1 = \frac{2\pi}{\lambda}, \text{ and } k_2^2 = k_1^2\,(\varepsilon + i2c\lambda\sigma),$$

where ε is the dielectric constant of the ground referred to air as unity, σ is the conductivity of the ground in electromagnetic units, c is the velocity of light in cm. per sec., λ is the wave-length in cm. and r is the distance in cm.

In the above equation, p is the 'numerical distance' as defined by van der Pol and Niessen and is slightly different for high frequencies from the 'numerical distance' used by Sommerfeld; this difference makes the above formula accurate for large values of the parameter b and free from the errors which Rolf[5] made by using the Sommerfeld 'numerical distance'.

Rolf used equation (1) with the lower sign reversed on the integral for computing the field intensity from a distant radio transmitter. Correcting this error in sign, I have found that the following empirical formula for the field intensity may be determined from equation (1):

$$F = \frac{c}{r} \sqrt{P} \left[f(p_0) - \sin b \sqrt{\frac{p_0}{2}}\, e^{-\frac{5}{8}p_0} \right] \ldots\ldots (2)$$

This formula gives the field intensity, F, in microvolts per metre when the radiated power from the transmitter is P kilowatts and is applicable for $b < 30°$, that is, for frequencies less than about 10,000 kc./s. for transmission over ground of average conductivity about 10^{-13} E.M.U. The quantity in the square brackets is the 'attenuation factor' and reduces to $f(p_0)$ in the case $|k_2^2| >> k_1^2$. This was the case discussed by Sommerfeld, and values for $f(p_0)$ are given by Rolf in his first paper—van der Pol[6] also gives the following empirical formula for $f(p_0)$:

$$f(p_0) = \frac{2 + 0{\cdot}3p_0}{2 + p_0 + 0{\cdot}6p_0^2} \ldots\ldots\ldots (3)$$

Formula (2) is limited in this application to a plane earth, the actual ground wave field intensity being influenced by the curvature of the earth at the greater distances, this effect being the predominating influence at sufficiently low frequencies.

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March 8.

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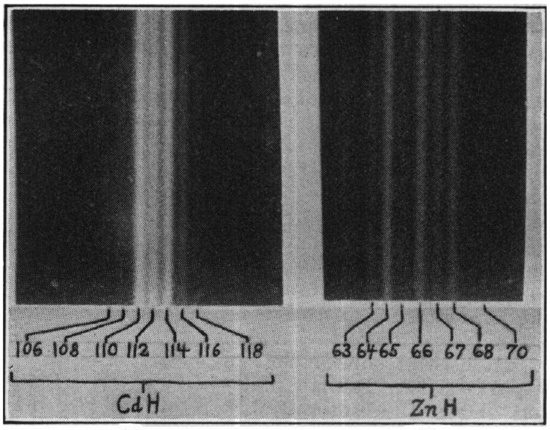
Band Spectroscopic Observations of the Isotopes of Zinc and Cadmium

ACCORDING to earlier mass-spectroscopic investigations by Aston[1], cadmium has the following isotopes arranged in order of their abundances: 114, 112, 110, 111, 113, 116. Later, two additional isotopes, 108 and 118, were observed by one of us[2], as a result of an investigation of the band spectrum of cadmium hydride.

Recently, Aston[3] has reported the discovery of three new cadmium isotopes, 106, 108, 115, but no evidence of the existence of Cd^{118} was obtained. As Cd^{106} appeared to be more intense than Cd^{108}, and the former isotope had not been mentioned by Svensson, Aston concludes that these results are not reliable; in particular, that the existence of Cd^{118} must be considered as rather dubious.

Our spectrograms, on which the above mentioned observations were based, did really give indications of lines corresponding to Cd^{106}, but were not published because of their spurious appearance as compared to the lines of $Cd^{108,118}$ which were present in some thousands of groups in the spectrum. As may be seen from Fig. 1 (*a*) representing the group at λ 4728 A. and corresponding to R_2 $(18\frac{1}{2})$ in $(v'=0;\ v''=3)$ of the $^2\Sigma \rightarrow {}^2\Sigma$ transition, Cd^{106} is present, although having decidedly less intensity than $Cd^{108,118}$. This intensity relation seems to hold throughout the observed spectrum. The existence of odd isotopes in cadmium could not be verified[2] on account of insufficient separation of the even components in a group.

The isotopes of zinc have also been the subject of several investigations, contradictory results having been obtained. Thus according to Aston[4], the following isotopes are present: 64, 65, 66, 67, 68, 69, 70. Bainbridge[5], however, was unable to observe $Zn^{65,69}$. From an unpublished investigation on the band spectrum of zinc hydride, one of us (G. S.) observed the following isotopes: 64, 66, 68, 67, 65, 63, 70, their abundances being in the order in which the numbers are given. Thus agreement is found with the results of Aston regarding Zn^{65} (not observed by Bainbridge) and vice versa regarding Zn^{69}. Our new isotope Zn^{63} is clearly visible in Fig. 1 (*b*), representing the group at λ 4035·0 A. and corresponding to R_1 $(33\frac{1}{2})$ in $(v'=0;\ v''=0)$ of the $^2\Pi_{3/2} \rightarrow {}^2\Sigma$ transition. The line corresponding to Zn^{63} is far more intense than that of Zn^{70}, which is too faint to appear on the reproduction, although clearly visible on the original plates.



(*a*) (*b*)

Our statements regarding the isotopes of zinc and cadmium are based on observations of extensive regions in the spectra of their hydrides. Some thousands of line groups have been measured in each spectrum, the isotope separations being in perfect agreement with the theory of isotope effects in band spectra. We would suggest, therefore, that the disagreement between band spectroscopic and mass-spectroscopic observations regarding the existence of isotopes does not indicate the unreliability of the former method but must be explained in some other way.

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March 20.

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