of the ionization density ($N$) in these low regions of the ionosphere. The collisional frequency ($\nu$) is high at such levels, and in the $C_1$ region it is perhaps comparable with $2\pi f$. Conditions favourable for reflection (or penetration) may be brought about either by an increase (or decrease) of $N$ or by a decrease (or increase) of $\nu$. It is quite conceivable that the atmospheric density and, along with it, $\nu$, varies from hour to hour at such levels, and the abnormalities observed in Fig. 2 may have been caused either by a variation of $N$ or by a variation of $\nu$ or by both occurring simultaneously.

S. K. MITRA.

London.
July 5.

## Existence of a Surface Wave in Radio Propagation

IN the mathematical development of the problem of radio propagation over plane earth, Sommerfeld[1] expressed his solution in the form of three terms, one of which he identified with the surface wave of Zenneck[2]. Curves calculated from Sommerfeld's formula have been given by Rolf[3]. Weyl[4], approaching the problem in a different manner, obtained a solution which did not explicitly contain this term. A formula given by Norton[5] gives values agreeing with Weyl. It appears that Weyl was of the opinion that his result was numerically equivalent to that of Sommerfeld. The purpose of this letter is to point out that this is not true, that the evaluation of Sommerfeld's formula by Rolf differs from the formulæ of Weyl and Norton by exactly the 'surface wave' component, and to give the results of a recent experiment showing the Weyl–Norton values to be the correct ones, which raises a question as to whether surface waves do or do not physically exist.

Previously available experimental data that might be used to decide which expression is correct have, unfortunately, been obtained under conditions for which Sommerfeld and Weyl do not differ greatly. For ultra-short wave propagation over deep fresh-water, however, their results differ enormously. To make a test under these crucial conditions, an experiment on the propagation of 2-metre waves has been conducted over Seneca Lake, New York State. The variation of the field with distance was found to agree well with Weyl. At a distance of about 1·8 km., where Sommerfeld's formula gives values about 1,000 times that of Weyl, the field was studied as a function of antenna height and polarization. Whereas Sommerfeld's expression for the surface wave gives values decreasing with height, the measured field actually increased. At the greater heights, the field was independent of polarization, as it should be if there were no surface wave. Since there is no uncertainty in the correct formula to use for horizontal polarization, this comparison showed that the field at the earth's surface was about 0·001 of the value predicted by Sommerfeld. It seems evident that a revision of the Sommerfeld–Rolf curves is required for propagation over all types of ground for which the dielectric constant cannot be neglected.

CHAS. R. BURROWS.

Bell Telephone Laboratories, Inc.,
Deal, New Jersey.
July 14.

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## Specific Ionization of Cosmic Radiation

AFTER Danforth and Ramsay's recent publication[1] I think it would be of interest to give here briefly the results of similar work, carried out last year, the conclusions of which have been proposed as a thesis at the University of Brussels (April 29, 1936) but cannot be published *in extenso* in a periodical before December next.

The problem is to measure the specific ionization of a penetrating radiation (cosmic radiation, fast electrons, etc.) by the comparison of the efficiency of a Geiger-Müller counter (single impulse or coincidence) corresponding to different internal pressures.

This method was indicated by Tuwim[2] in 1931, and by us[3] in 1933. The integration necessary for the determination of the mean length of the internal path was resolved by Tuwim and Kolhörster[4] (1933) in a particular case; unfortunately, that case was not very convenient for the precise determination of specific ionization.

I have solved that integration graphically and numerically with sufficient approximation (error less than one per cent) in the general case of two identical counters, parallel, connected for counting coincidences.

This calculation shows that the approximate formula used by Danforth and Ramsay, and by me in 1933, was definitely different from the true one (more than five per cent discrepancy). I had also shown experimentally that a single pair of ions gives a discharge of the counter with a probability of 0·999; the corrections due to showers, accidental coincidences, recovery time, latent time, barometric effect, etc., have been discussed and taken into account.

The counters used had an over-voltage range of the order of 1,000 volts, a reproducibility better than 0·5 per cent during many months, and a residual frequency of impulses that may be neglected.

The following results were found: Total cosmic radiation:

| | | |
|---|---|---|
| Specific primary ionization: | | |
| Hydrogen | $5{\cdot}96 \pm 0{\cdot}07$ cm.$^{-1}$ | (0°–760 mm.) |
| Helium | $5{\cdot}96 \pm 0{\cdot}15$ | ,, |
| Argon | $29{\cdot}40 \pm 2{\cdot}0$ | ,, |
| Specific total ionization: | | |
| Argon | $71{\cdot}40 \pm 2{\cdot}0$ | ,, |

Absolute intensity of cosmic radiation (number of rays crossing per second a sphere of 1 cm.$^2$ of cross-section):

Brussels (reduced to sea-level) (760 mm.):

$$0{\cdot}0266 \pm 0{\cdot}0003 \text{ cm.}^{-2} \text{ sec.}^{-1}.$$

The concordance between the experimental results and the calculated curve (mean error, 0·9 per cent, equal to the calculated most probable error due to uncertainty of readings) indicates a remarkable homogeneity of specific ionization of the different components of cosmic radiation (primary and secondary).

MAX G. E. COSYNS.

Physical Laboratory,
"Fondation Médicale Reine Elisabeth",
Brussels. July 21.

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