Letters to the Editor

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Radio Exploration of the Ionosphere

(*a*) *Measurement of the earth's magnetic field in the ionosphere.*

The discovery[1] of magneto-ionic doubling of wireless echoes returned from the ionosphere and its explanation[2] in terms of the theory of double refraction have provided us with a method of estimating the intensity of the earth's magnetic field at the level from which the waves are reflected. The way in which the earth's magnetic field is related to the observational data was indicated by Appleton and Builder, who showed that, under conditions of quasi-longitudinal propagation, relative to the direction of the magnetic field, we have

$$H = \frac{2\pi m}{e}\,(f_e - f_o) \quad . \quad . \quad . \quad . \quad . \quad (1),$$

where H is the total magnetic intensity, f_e and f_o are respectively the critical penetration frequencies of the extra-ordinary and ordinary waves for any particular region, and e and m are the charge and mass of an electron. For conditions of quasi-transverse propagation, on the other hand, the corresponding formula is

$$H = \frac{2\pi m}{e}\left(\frac{f_e^2 - f_o^2}{f_e}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad (2).$$

It was further shown by Appleton and Builder that their experimental results, obtained under conditions of quasi-transverse propagation, agreed approximately with (2) when the value of the earth's magnetic field at the ground was used for H, so that their observations could be interpreted as indicating either the approximately quantitative correctness of the magneto-ionic theory or that the magnetic field in the ionosphere does not differ very markedly from its value at ground level.

If we assume the quantitative correctness of the magneto-ionic interpretation of the results, it is obvious from equations (1) and (2) that we have here a method of measuring the magnetic field in the ionosphere. During the past year, I have therefore made as careful measurements as possible of the value of H for the upper ionised region during nocturnal conditions when critical frequency measurements are most reliable, my object being to look for small variations of H such as might be caused by the upper-atmospheric currents envisaged in present-day theories of terrestrial magnetism[3].

The detailed examination of these results is still in progress, but one result of interest has emerged from the first series of two hundred measurements. The average value of H calculated from (2) is found to be 0·42 gauss. Now the value of the earth's total magnetic field at the surface of the earth in south-east England is 0·467 gauss, so that the radio observations suggest that the average magnetic field in the ionosphere is about 10 per cent less than its value at the ground.

Now, according to Schmidt, the earth's magnetic field intensity above the surface may be expressed, as a first approximation, by $H_0\ (1 - 3h/R)$ where H_0 is the ground value, h the elevation and R the earth's radius. The values of the magnetic field at 200 and 300 km. above the earth's surface in south-east England should therefore be 0·42 and 0·40 gauss respectively. It will be seen that the value obtained by the radio methods is of about this order of magnitude.

(*b*) *A new method of ionospheric investigation.*

One of the fundamental quantities measured in the study of the ionosphere is the group-time for a signal to travel to the stratum of reflection and back to the ground. To measure such a group-time, we must impress some kind of mark on the signal in order to recognise it on its return. Now the essential characteristics of an electric wave are frequency and amplitude, and the two basic methods of group-time measurement are thus those involving frequency-modulation and amplitude-modulation. It must not be assumed, however, that in their simple forms they always represent the most convenient ways of marking a signal for group-time measurements, and I have recently found that there are sometimes advantages in combining the methods so as to produce a frequency change on a pulse emitter. It will readily be seen that in doing this we extend the frequency range examined in the experiment and obtain, in effect, information comparable with that which we should get with an extremely brief pulse. This means that we can investigate the structure of echoes which are normally unresolved.

As an example of the use of this combination method, as I propose to call it, let us consider the case of an unresolved magneto-ionic doublet. If the mean frequency of the emitter is varied continuously through a sufficiently large range, we get interference effects in the echo itself, so that any component amplitude varies through a series of maxima and minima. If, in this case, a linearly polarised receiver aerial is used, we have :

$$c\,\frac{\Delta n}{\Delta f} = P'_o - P'_e \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where P'_o and P'_e are the equivalent paths of the ordinary and extraordinary waves, Δn the number of interference fringes produced by a change of frequency Δf and c is the velocity of light.

When apparatus is available for providing automatic maintenance of sender and receiver tuning during the frequency change, such as that first described by Gilliland, the usefulness of the combination method may be strikingly demonstrated. For example, in a test carried out at Slough at 1530 on March 8, 1934, using an apparatus of similar principle designed by Mr. L. H. Bainbridge-Bell, an alteration of mean frequency of from 4·0 to 4·2 mc./s. produced five interference fringes in a first order F-region reflection. This corresponds to an equivalent path difference for the two magneto-ionic components of 7·5 km., or to a difference in equivalent height of 3·75 km. It is obvious that differences in equivalent height of 1 km. or less can be detected in this way.

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[1] Appleton and Builder, *Proc. Phys. Soc.*, **44**, 76, January 1932.

[2] Appleton and Builder, *Proc. Phys. Soc.*, **45**, 208, March 1933.

[3] Cf. McNish, *Terr. Mag. and Atmos. Elect.*, **39**, 5, March 1934.