example, 300-400 metres), night-time reception is dependent almost entirely on the upper indirect ray; and evidence is not lacking that, due to the more effective reflection by the ionised layer at smaller grazing angles, the signal strength maximum may in some cases increase with increase of distance from the transmitter.

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Cambridge,
February 21.

The Propagation of Radio Waves over the Earth.

Among the facts to be explained in a satisfactory theory of the propagation of radio waves over the earth's surface are the curvature of the rays in transmission between stations far apart, the absorption during transmission, the peculiar phenomenon of fading, in which the magnitude of the received wave fluctuates more or less rapidly, the differences in transmission in different directions over the earth, and the extraordinary differences in the transmission of long and short waves.

This letter is to outline a new theory of transmission which accounts quantitatively for many previously unexplained facts of radio transmission. A detailed treatment of important cases will appear shortly.

The atmosphere to a considerable height above the earth contains ions which react upon electromagnetic waves and, as shown by Larmor (*Phil. Mag.*, Dec. 1924), may account for the bending of long waves around the earth. His explanation, however, does not show the large and characteristic differences between short and long wave transmission, which become especially marked in passing through the region between 100 and 200 metres. Other theories, also, have the defect of predicting entirely incorrect results for short wave-lengths.

The theory now developed takes into account both the earth's magnetic field and the distribution of ionised particles in the atmosphere. It is found that this field, together with the electrons, produces marked selective effects at wave-lengths between 100 and 200 metres, and that these effects are different for different directions of transmission and for different planes of polarisation of the wave. A summary of the effects follows:

For the case in which the electric force of the wave is parallel to the earth's magnetic field, the only effect is due to a variation in ionic density above the earth. This case is realised practically only over very limited areas of the earth's surface.

For transmission in any other direction or for any other direction of the electric field, four effects are in general produced, namely, the plane of polarisation of the wave is rotated by an amount depending upon the density of free electrons, the magnetic field, and the frequency. This effect reverses at the critical frequency, which, for a field of 0·5 gauss, is 1400 kilocycles (214 metres). The second effect is that of double refraction in the medium, producing two waves of different velocities and polarisations. The third effect is a bending of the rays due to a variation in ionic concentration, as in Larmor's case, but, due to the magnetic field, this bending also, in most cases, reverses at the critical frequency, so that if long waves bend down in a certain region, short waves will be deflected upwards in the same region. The fourth effect is a bending of the rays due to variations in the magnetic field strength, and this effect also reverses at the critical frequency.

The general solution of this problem cannot be given in this note, but some interesting special cases will be described.

For transmission from a vertical antenna along a magnetic meridian the electric vector tends to be rotated, and, when this rotation becomes equal to 90°, the usual methods of reception produce no signals; hence we should expect, in general, better reception of east-west than of north-south signals at certain points. Also, since the plane polarised ray can be resolved into two circularly polarised rays travelling with different velocities, under certain conditions both components may not be able to travel over the same path between two points.

The rotation of the plane of polarisation for transmission along the magnetic field is rather large; for example, the electric vector in a wave 2 km. long will turn from vertical to horizontal in about 80 wave-lengths if there are present only 10 free electrons per cubic centimetre in a layer for which the mean free path is sufficiently long for free motion. A wave 100 metres long will rotate through the same angle, but in the opposite direction, in about 5000 wave-lengths or 500 km. For larger ionic densities, appropriate to high levels, the waves may be rotated very rapidly, which is one of the causes of variable transmission along a magnetic meridian.

For transmission at right angles to the magnetic field, we find double refractions with the ordinary ray unaffected by the magnetic field and the other selectively affected.

In all these cases, the variation in the number of ions and in the magnetic field at different heights above the earth produces deflexions of the rays which may be calculated.

The introduction of a resistance term into the equations of motion of the electron leads to an attenuation factor in the equations of wave-motion. Thus, for transmission parallel to the magnetic field, the exponential term involves the reciprocal of the square of the frequency for frequencies sufficiently large compared to the critical value. This means, therefore, that attenuation due to this cause falls off rapidly as the frequency is increased. At the other extreme the same expression is found to apply, except that in place of the transmitted frequency, the critical value is substituted. Hence in this range attenuation due to this cause is constant. There are, of course, other causes of attenuation—for example, the conductivity of the earth.

When the frequency is near the critical value, large anomalous effects occur. For example, the wave may be required to travel over a widely different path by a slight change in either the magnetic field or the ion density. The signal may arrive at the receiver from several directions simultaneously or successively, producing fading or apparent change of direction. The absorption may become extremely high for certain rays.

The detailed theory, with its predictions, will be published soon.

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February 6.

Molecular Symmetry in Crystal Structure.

It has been pointed out by Clark[1] that there is a great similarity between the structures of the four alkali polyhalides KI_3, CsI_3, $CsIBr_2$, and $CsICl_2$. They have the same arrangement of atoms in unit parallelepipeda, if the unit cells are chosen so as to contain one molecule. The arrangement is with the metal atoms at the corners of the cell and the halogen atoms inside the cell and in a line on the body diagonal.

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[1] A. L. Clark, Pro. Nat. Acad. Sci., 9, 4, 1923, p. 112.