SHORT COMMUNICATIONS

IONOSPHERIC DEMODULATION OF RADIO WAVES AT VERTICAL INCIDENCE*

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Introduction

In a previous communication, Aitchison and Goodwin (1955) have described an investigation carried out at the University of Adelaide on the demodulation of radio waves at vertical incidence. At a frequency of 1550 kc/s, which is close to the local gyro frequency of approximately 1600 kc/s at the height of the E layer of the ionosphere, marked reductions in the modulation depth were observed on the sky wave. The experimental results tabulated in the previous communication suggested that the effect was greatest at a modulation frequency of the order of 800–1500 c/s. From subsequent measurements it is apparent that, in the case of F-layer reflection the demodulation was greatest at a modulation frequency of, very approximately, 1 kc/s ; in the case of E-layer reflection, the degree of demodulation did not vary markedly with change of modulation frequency.

Interpretation

Calculation from magneto-ionic theory of the absorption coefficients of the extraordinary and ordinary components in the E layer shows that the former is vastly greater than (of the order of 2000 times) the latter at 90 km height at the frequency used. Virtually the whole of the extraordinary component will be absorbed in the lower E layer, while the ordinary component will pass through this region and be reflected from either the F layer or a higher region of the E layer. We therefore consider the possibility that the demodulation may be due to wave interaction, with the ordinary and extraordinary components acting respectively as " wanted " and " disturbing " waves. (For an account of the phenomenon and theory of wave interaction see Huxley (1952).) Even though, as is stated later, it appears that the observed degree of the demodulation is much greater than would be expected from the theory of wave interaction, the following analysis is of value in that it indicates that the demodulation is occurring in the E layer. It is not, however, to be assumed that interaction between the two magneto-ionic components is necessarily being regarded as the cause of the observed demodulation.

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We represent the ordinary wave entering the region of absorption of the extraordinary wave from below by

$$^{0}E_0(1+M\cos\omega t)\cos pt=E_0(1+M\cos\omega t),$$

where M=modulation depth,
$p=2\pi\times$carrier frequency,
$\omega=2\pi\times$modulation frequency.

Let T_ω be the modulation depth impressed on it at the fundamental frequency $\omega/2\pi$ in passing once through the region of absorption of the extraordinary wave. (The theory of wave interaction shows the existence of a harmonic term. This may be ignored in the present case, since M had the value 20 per cent., and (see Huxley 1952, equation (**36**)) $T_{2\omega}<\frac{1}{4}MT_\omega$, i.e. $T_{2\omega}<T_\omega/20$.) Then, from Huxley (1952), equation (**39**), we have for the wave emerging from the region the expression

$$E_0(1+M\cos\omega t)[1+T_\omega\cos(\omega t-\varphi_\omega-\pi)].$$

If the wave travels a distance $2l$ between emerging from the region and re-entering it after reflection, then the wave finally emerging from the region will be given by

$$E_0'(1+M\cos\omega t)[1+T_\omega\cos(\omega t-\varphi_\omega-\pi)][1+T_\omega\cos(\omega t-\varphi_\omega-\pi+2l\omega/c)]. \quad \ldots\ldots\ldots (\mathbf{1})$$

For T_ω we substitute (Huxley 1952, p. 87) the expression

$$T_\omega=T_0/[1+(\omega/Bn)^2]^{\frac{1}{2}}=T_0/(1+\tan^2\varphi_\omega)^{\frac{1}{2}}=T_0\cos\varphi_\omega.$$

(Huxley (1956) has shown that the term Bn should be substituted in the theory of wave interaction for G_ν^-; the result $T_\omega=T_0\cos\varphi_\omega$ is not affected by this substitution.)

The expression (**1**) then becomes, since T_0 is small,

$$E_0'[1+M'\cos(\omega t-\psi_\omega)],$$

where

$$M'\cos(\omega t-\psi_\omega)=M\cos\omega t+\tfrac{1}{2}T_0[\cos(\omega t-\pi)+\cos(\omega t-\pi-2\varphi_\omega)+ \ldots +\cos(\omega t-\pi-2\varphi_\omega+2l\omega/c)+\cos(\omega t-\pi+2l\omega/c)]. \quad \ldots\ldots\ldots (\mathbf{2})$$

This expression is represented diagrammatically in Figure 1. Here the triangle CDE rotates about C as ω increases, and also the angles ABC and CDE decrease with increasing ω. Thus a minimum value of M' is to be expected if $2l\omega/c\simeq2\pi$ (or multiples thereof; but minima beyond the first are unlikely to be of consequence because of the increase in the value of $2\varphi_\omega$), and since, for F-layer reflection, l is approximately 150 km, this minimum occurs at a modulation frequency $\omega/2\pi$ of approximately 1000 c/s, in agreement with the experimental result.

In the case of E-layer reflection, the term $2l\omega/c$ is virtually zero, and (**2**) becomes

$$M' \cos(\omega t - \psi_\omega) = M \cos \omega t + T_0[\cos(\omega t - \pi) + \cos(\omega t - \pi - 2\varphi_\omega)],$$

which is represented diagrammatically in Figure 2. Here, as ω increases, A moves around the semicircle BAC, and it is apparent that φ_ω may increase from zero to a relatively large value without greatly changing the value of M'. Thus

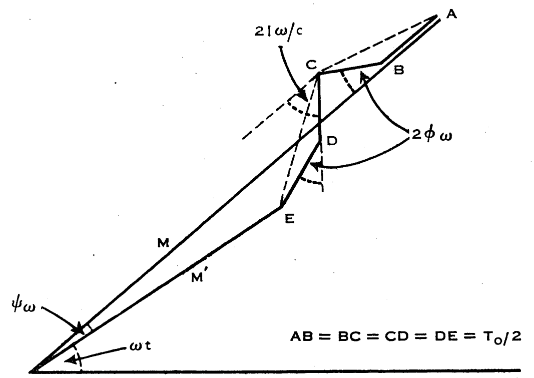

Fig. 1.

the lack of marked dependence of modulation depth on modulation frequency is qualitatively explained.

It must, however, be stated that, if T_0 is evaluated from the theory of wave interaction (see Huxley 1952, equation (**41**)), the value obtained in the present case is much too small to account for the observed degree of demodulation.

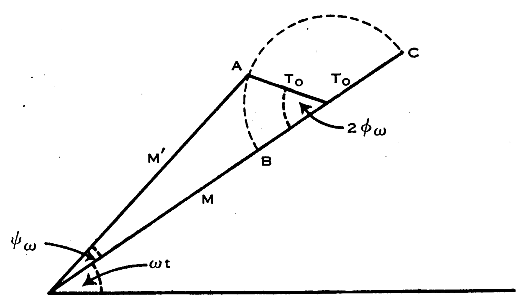

Fig. 2.

The agreement between theory and experiment regarding the variation of the degree of demodulation with modulation frequency would appear to indicate the correctness of the assumption that the demodulation is occurring in the E layer and that the wave is affected on both its upward and downward paths. But the mechanism of the demodulation appears to require further investigation.

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