Nonlinear reflectivity of high-power radio waves in the ionosphere

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An important result of earlier ionospheric modification experiments performed at Platteville, Colorado, was the discovery that the reflectivity of the ionosphere was greatly reduced in the reflection region of a high-power radio (pump) wave[1]. Because the reflectivity of low-power diagnostic waves passing through the modified region with frequencies from just below the pump wave frequency up to the F region critical frequency were reduced, the phenomenon was termed wide-band absorption (WBA). Subsequent experimental and theoretical work (for review see ref. 2) has led to the conclusion that WBA is due to the scattering of radio waves from field-aligned irregularities into plasma waves. These irregularities are generated by the interaction of the pump wave and the ionospheric plasma but the mechanism by which this occurs is not completely understood. It is evident, however, that in the process the pump wave itself undergoes WBA. In a recent campaign using the Max-Planck Institute ionospheric modification facility at Ramfjordmoen, near Tromso, Norway, the existence of WBA at high latitudes was confirmed by experiments using low-power diagnostic waves passing through the reflection region of the high-power radio wave[3,4]. As we report here, during an experiment to measure the effect of WBA on the pump wave itself, the essentially nonlinear nature of the interaction between the high-power radio waves and the ionosphere was demonstrated in a new and striking way.

The experiment consisted of measuring the amplitude of the reflected 5.423-MHz pump wave at a receiver about 40 km south of the transmitter while the effective radiated power (ERP) of the pump wave was being changed. The changes in ERP consisted of 40 steps of 6.5-MW increases from 0 to 260 MW (full power) and then 40 incremental decreases of 6.5 MW down to 0 MW, the steps being made at 9-s intervals. One cycle was thus completed within 12 min and was repeated several times.

Figure 1 shows a record of the reflected pump signal during this experiment. The reflected signal increases suddenly during the first step from 0 to 6.5 MW ERP and then continues to increase but less rapidly, during successive increases in ERP. This behaviour is a result of the usual WBA effect and persists up to ~40–50% of full power. However, further increases in power produce a completely new type of behaviour in which the reflected signal decreases with increasing ERP.

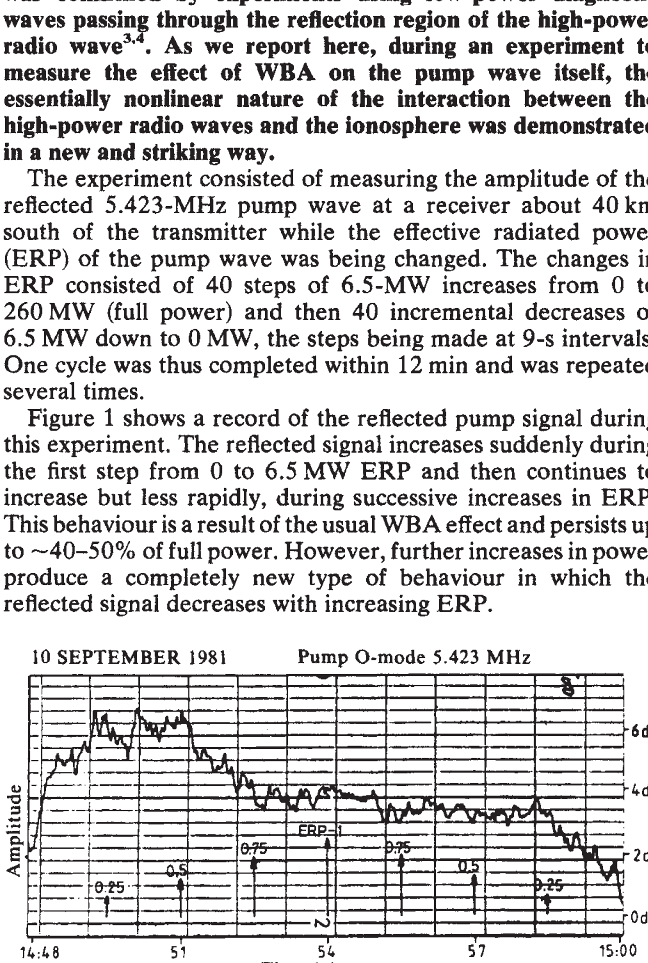

Fig. 1 Record of reflected pump wave amplitude during one 12-min cycle.

This result is a direct consequence of the dependence of the reflectivity of the ionosphere on the amplitude E_0 of the pump wave. If the absorption coefficient of the ionosphere under the influence of the pump wave is $\chi(E_0)$, the reflected amplitude E_R after the wave has travelled twice through a thickness L_0 of modified ionosphere is

$$E_R = E_0\, e^{-2L_0\chi(E_0)} \quad (1)$$

from which it can be seen that

$$\partial E_R/\partial E_0 = e^{-2L_0\chi(E_0)}\,(1 - 2L_0E_0\partial\chi/\partial E_0) \quad (2)$$

Thus, as long as χ is an increasing function of E_0 (which theory predicts to be the case), then expression (2) shows that E_R will increase with E_0 when E_0 is less than a critical value, E_c, but that E_R will decrease with increasing E_0 when E_0 exceeds E_c, where E_c is given by

$$E_c = 1/(2L_0\partial\chi/\partial E_0) \quad (3)$$

This result may have far-reaching practical implications, especially in the field of telecommunications. It is normally assumed that in a broadcasting system, the signal amplitude at a remote receiver can be increased by increasing the radiated power of the transmitter. The present results suggest that a certain optimum power exists above which the signal received via the ionosphere at a remote site will be reduced.

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1. Cohen, R. & Whitehead, J. D. *J. geophys. Res.* **75**, 6439–6445 (1970).
2. Fejer, J. A. *Rev. Geophys. Space Phys.* **17**, 135–153 (1979).
3. Jones, T. B., Robinson, T., Kopka, H. & Stubbe, P. *J. geophys. Res.* (in the press).
4. Stubbe, P., Kopka, H., Jones, T. B. & Robinson, T. *J. geophys. Res.* (in the press).

Unusual luminescence behaviour of terbium phosphate glasses

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While preparing a terbium-containing phosphate glass, an intense emission of green light was observed when the melt was poured into a metal mould. This emission was easily visible to the naked eye and was only observed on quenching of the melts. To our knowledge this phenomenon, termed 'cooling-induced luminescence (CIL)', has not previously been reported. Experimental evidence suggests that the CIL may be related to a thermally induced shift in the oxidation-reduction balance in the melt. A similar phenomenon was also observed with europium phosphate melts.

To determine the exact nature of the emission, a series of spectra was recorded using a quartz prism spectrometer, taking successive photographic film exposures, as the melt cooled. Figure 1 shows the emission spectra obtained during the cooling of a melt of terbium metaphosphate, $Tb(PO_3)_3$, and the emission spectrum obtained by exciting the glass, at room temperature, with an UV light source fitted with a 'black light' filter. The CIL peaks agree well with the UV-excited peaks and correspond to the known fluorescence spectrum of Tb^{3+}. The peaks at 412 and 436 nm in the spectrum taken at 1,284 °C also correspond to known terbium emissive transitions, even though they were not observed in the UV-excited spectra. The spectra in Fig. 1 obviously represent a superposition of the terbium fluorescence lines and the thermal emission continuum of the hot melt. Figure 2 shows the thermal emission continuum of a metaphosphate melt, $La(PO_3)_3$, which does not contain an ion exhibiting fluorescence.

Quenching of the melt was required to observe CIL. Table 1 summarizes the effect of cooling history and rate for $Tb(PO_3)_3$. If