Demodulation of high-power low-frequency waves in the subauroral ionosphere in the range of geometric pulsations

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Demodulation of intense signals from a subauroral VLF transmitter, operating at frequencies $f_0 = 17$–35 kHz with amplitude modulations at $f_m = 0.5$ Hz was observed. From an analysis of the amplitudes (~0.5–5.0 mγ) of the three magnetic components of the demodulated waves it is concluded that the demodulation is due to excitation of a meridional electric current in the ionosphere as a result of the heating nonlinearity. The demodulation process has a tendency to saturate when the power is increased, and the relaxation time is ~30 msec.

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An experiment "Juliana-3" aimed at observing the effects of intense modulated signals from a subauroral VLF transmitter to the ionosphere and to the magnetosphere of the earth ($\Phi \sim 60°$, carrier frequency $f_0 = 17$—35 kHz, amplitude-modulation frequency $f_m = 0.02$—0.5 Hz) was performed in December 1976. The signal duration ranged from 1 minute to 1 hour with a total duration of the runs 3 hours in intervals 3 to 6 Am Moscow time in the three nights of the tenth, twelfth, and fourteenth of December 1976. Most of the time, an electromagnetic wave was emitted with amplitude modulation at frequency $f_m = 0.5$ Hz, and it is precisely in this regime that the effect of demodulation in the ionosphere was observed. The demodulation signal was observed at a distance ~500 km northwest of the VLF transmitter using a special three-component recorder of geomagnetic pulsations (with periods 0.2—120 sec) having a sensitivity $\sim 1 m\gamma/\sqrt{Hz}$ for pulsations of the type PC-1. The output of the recorder was connected to an infralow-frequency active gyrator filter with high Q tuned to a frequency 0.5 Hz and having a time constant 6 sec. The filter signal was recorded with an automatic recorder (5 mm/sec), which also recorded all the components of the geomagnetic pulsations in a broad band, the time markers, and the envelope of the transmitter signals. In addition, the pulsations of type PC-1 in the range of periods 0.2—5 sec were recorded with an analog tape-recorder with slow tape speed ~1 mm/sec. The tape signals were analyzed with the aid of a "Sonograf" spectrum analyzer with the speed of the magnetic tape suitably increased (1:240).

In all three runs, the demodulation signal with frequency $f_m = 0.5$ Hz was registered quite reliably at the output of the narrow-band filter, and was particularly intense for the D component of the magnetic field. Figure 1 (upper traces) shows typical records of the narrow-band D channel for signal frequen-

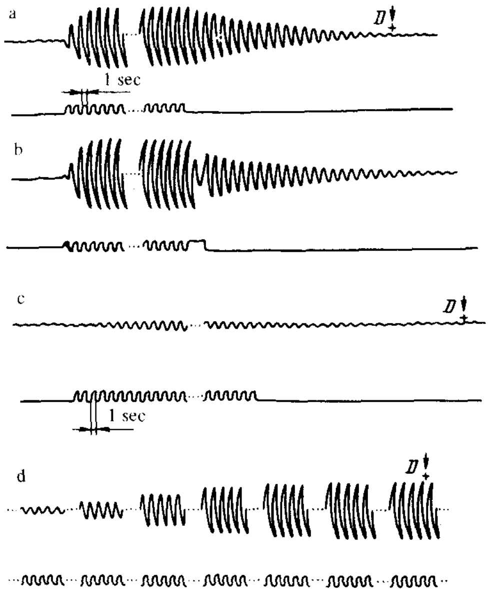

FIG. 1.

cies 35 kHz (1a), 28 kHz (1b), and 17 kHz (1c). The lower trace of each record shows the envelope of the initial transmitter signals.

The signal amplitudes were 4.0, 5.1, and 0.7 $m\gamma$, respectively. Since the transmitter radiation power was approximately the same in these cases, this favors the ionosphere mechanism of excitation of the demodulation signal, since the coefficient of the transmission of the VLF waves through the ionosphere decreases with the increasing frequency. Figures 1(a) and 1(b) show that the process has a relaxation time ~20—30 sec, and it has been established with the aid of calibration that this is not connected with the attenuation of the recorder filter. Another feature of the demodulation mechanism is the tendency to saturation, as demonstrated in Fig. 1(d). These are typical records of the narrow-band D channel ($f_0 = 35$ kHz) with successive change of the signal power by a factor of two each from the maximum P_{max} to 0.02 P_{max} (from right to left). It is seen that the amplitude as a function of P varies linearly only at small values of P and practically ceases to increase at $P > 0.25\ P_{max}$.

Figure 2 shows sonograms of the dynamic spectra of the pulsations of each of the components in the interval 03^h—06^h local time on 14 December in the frequency band 0.1—2.0 Hz. The transmitter operated in the periods 03^h00^m—03^h20^m, 03^h25^m—03^h45^m, 03^h50^m—04^h10^m, and 05^h35^m—06^h00^m with modulation $f_m = 0.5$ Hz, with the power varied during the first and last periods. The demodulation signal could be clearly traced in the D channel (first and third harmonics of f_m), is seen in the Z channel at maximum signal power, and is practically invisible in the H channel. The results for the other runs are similar. This effect is possible in the case when the demodulation signal is excited by meridional currents in the atmosphere. We note that the appearance of relatively broad band radiation (0.5—0.7 Hz) in the time 04^h00^m—04^h40^m immediately after the additional VLF signal can be regarded as stimulation of geomagnetic pulsations, which does not contradict the conclusions of[1] and the

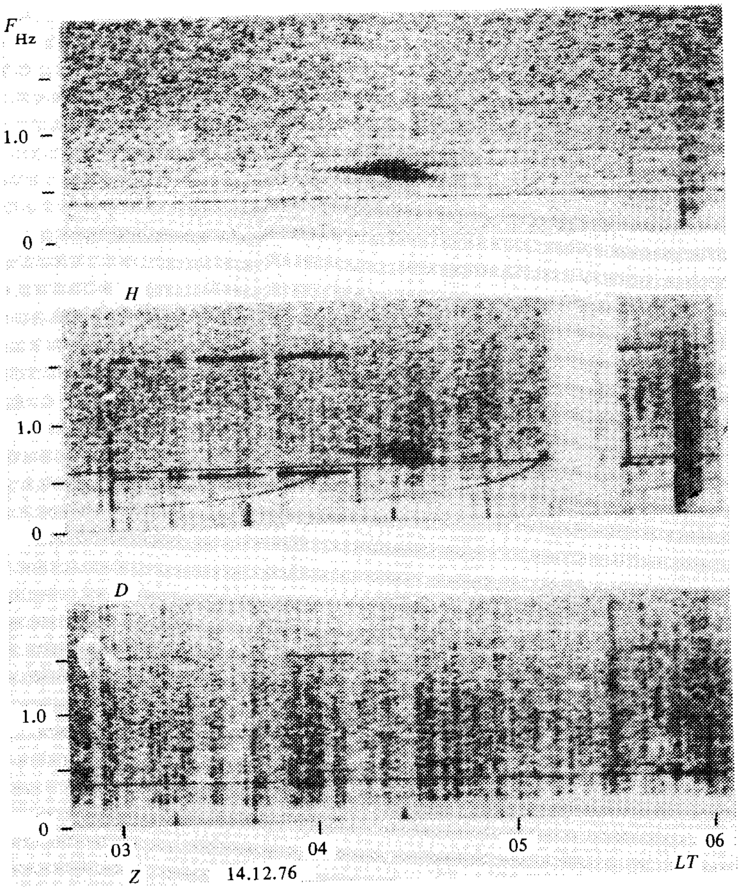

FIG. 2.

statistical estimates of[2,3]. However, the predominance of the *H* component of the radiation in comparison with other components indicates that the stimulation mechanism is different from the demodulation mechanism and possibly of magnetospheric origin.

The demodulation can result from heat-induced changes in the conductivity of the ionospheric currents. This assumption, advanced in[4], is used to explain the demodulation of a high-power SW transmitter in the VLF range. The major differences between the demodulation in our experiments and[4] are the following: the increased efficiency of demodulation (by 2—3 orders of magnitude), the shift of the perturbation region to height ~ 100 km as a result of the localization of the auroral ionospheric currents in that region; predominance of the perturbation of the Pederson conductivity in comparison with the Hall conductivity, which leads mainly to excitation of meridional current at the frequency f_m.

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