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THE WAVES OBSERVED IN THE ARAKS-EAST EXPERIMENT

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ABSTRACT

Experimental results of the Wave measurements over frequency range 0.1-5.0 MHz during the second launch of the ARAKS Experiment (15.02.75) are reported. The differences between the results of the first and the second launches are discussed.

INTRODUCTION

The second launch of Eridan rocket in French-Soviet experiment ARAKS took place during a substorm recovery phase which is believed to be the main cause of several phenomena differed the second launch from the first one [1]. Another reason for different results obtained in wave measurements particularly for whistler mode spectra was that rocket flight trajectory planes were oriented in a different way to the plane of Earth magnetic field line in the first and the second launches. In the first launch the rocket was directed to the magnetic North and in the second one to the magnetic East. Results of the wave measurements have been obtained with wide band equipment "Spectrum" [2, 3].

The emissions in the frequency range 0.2 - 4.5 MHz along the East flight are displayed on the Fig.1. The whistler mode $f \leqslant f_{He}$ may be seen in the 650 kHz vicinity. It is always correlated with gun injection whatever the duration of the pulse. The plasma mode frequency $f_p \leqslant f \leqslant f_{uh}$ is close to 3.1 MHz at the culmination (14 sequence) and decreases along the descent of the nose cone. Signals in the vicinity of $3f_{He}$ are clearly visible during the 8-th sequence of electron gun injection. Emissions have been also detected in the pauses between series of injection pulses and between pulses of injection in the same frequency ranges. Very strong U-shaped periodic signals have been detected near 2 MHz and 4 MHz along the descent part of trajectory (18, 20, 22 sequences), which may be connected with nonlinear demodulation of the "Spectrum" telemetry transmitter signal in turbulent plasma of supersonic flow round nose cone. The frequency of U-shaped emission have been decreasing in time.

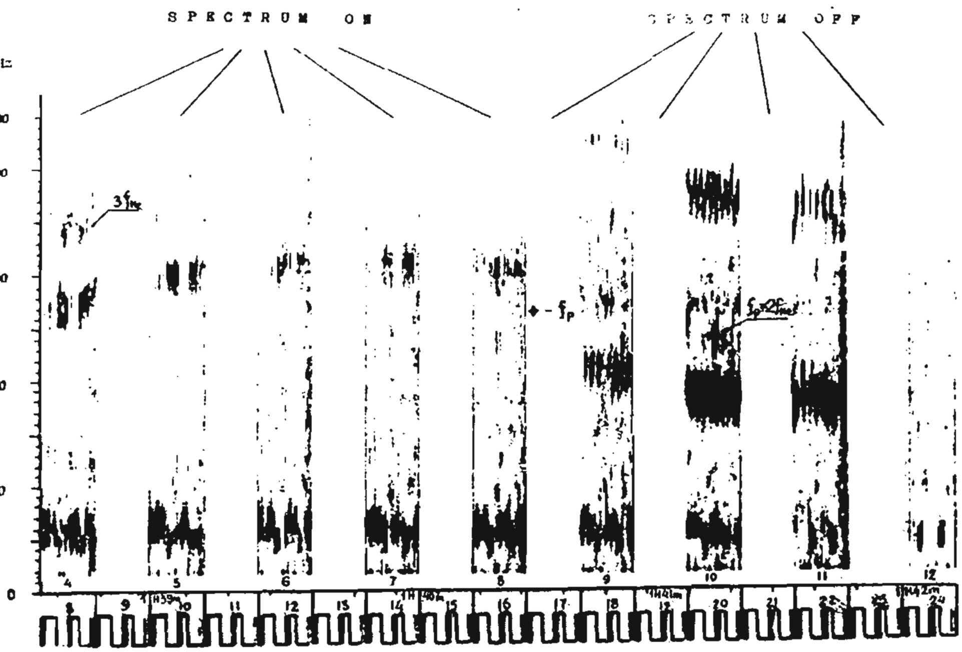

Fig.1 High frequency waves observed during the East flight displayed like a sonagram. At the bottom of the figure a theoretical scheme of the electron gun sequences is drawn. "Spectrum" equipment was being switched on every even sequence of the electron gun operation which is illustrated by periodic discontinuities in the sonagram.

THE WHISTLER MODE

Like in the North flight the form of the emission pulses of whistlers follows the envelope of the electron gun current. But in the North flight the whistler spectrum maximum was at the vicinity of 150 kHz [1,4] whereas the maximum of this mode is found to be of order 650 kHz in the East one. This experimental fact may be interpreted after taking into consideration that the observable frequency band is defined by mutual position of injector and receiver. For whistlers generated by the beam $\omega = k_{\parallel}u + m\omega_{He}$ $(m = 0, \pm 1, \ldots)$ for $m > 0$ signal may be detected by the receiver with coordinates $R_{\perp}/R_{\parallel}$ $v_{\perp g}/v_{\parallel g}$, where $R_{\parallel}$, $v_{\parallel g}$ and $R_{\perp}$, $v_{\parallel g}$ the distance between the rocket and separated nose cone and the wave group velocity along and traverse to magnetic field line correspondingly. When $\theta \sim 90^\circ$, $u \to 0$ the minimal detectable whistler frequencies are [5]:

$$f_{min} = \left[1 + (R_{\perp}/R_{\parallel})^2\right]^{-1}$$

If we substitute the meanings of $R_{\perp}/R_{\parallel}$ for both launches we obtain $f_{min} \sim 0.2$ (North) and $f_{min} \sim 0.56$ (East). The experimental values for 70° series of electron gun are [4]: $f_{exp} \sim 0.25$ (North) and $f_{exp} \sim 0.5$ (East)

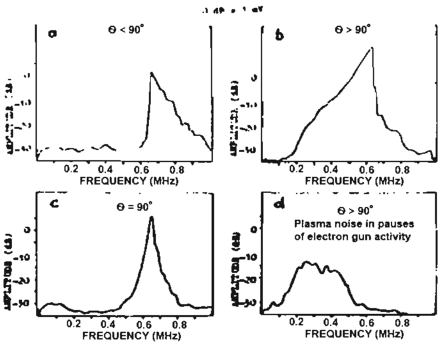

Fig.2 a,b,c - the spectra during injection; d - the spectrum in pauses

The dynamics of whistler mode spectrum as a function of injection pitch-angle is represented on Fig.2. Whistler spectra for $\theta > 90°$ and for $\theta < 90°$ are mirror images relative to 650 kHz and are symmetrical to it under $\theta \sim 90°$ values. Amplitudes of spectra components have reached a maximum of 3 mV over Δf = 10 kHz. The radiation received is modulated at the double of the spin frequency of the nose cone and at the spin frequency of the rocket. The second kind of modulation probably caused by different mechanisms in the North and East launches. Amplitude modulation by the rocket spin in the North launch is connected with plasma source activity with pitch angle of injection being kept constant, whereas in the East launch it was caused by variations of pitch-angle due to the rocket spin motion (the electron gun was installed with 30° angle to the rocket axis in the East launch).

THE PLASMA MODE

Emission in the plasma mode range correlated with electron gun operation is connected with the beginning of an electron pulse and has similar "pulsed" character as in Electron Echo I and ARAKS North experiments. Average level of signal at receiver input was 0.5 - 1 mV which slightly exceeds the level of plasma mode in the North launch ($\sim$200 μV). The spectra patterns of plasma mode in the East launch are obviously asymmetrical to maximum (a) and may have two local maxima in the case (b). The plasma mode is modulated by the rocket spin.

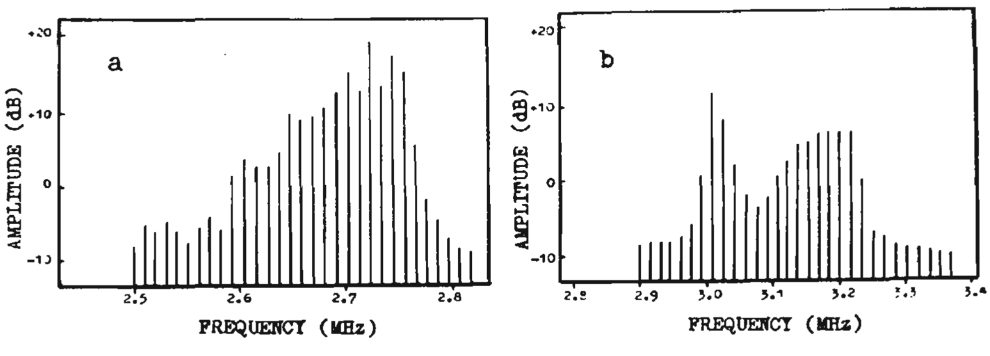

Fig.3 The plasma mode spectra for small pitch-angles; a - ascending part of trajectory, b - the trajectory culmination. 0 dB = 200 μV

THE BERNSTEIN MODES

Emission has been detected in the vicinity of electron gyrofrequency harmonics mainly at frequencies exceeding the local plasma frequency ($3f_{He}$ and $4f_{He}$). Emission has been reaching 0.75 mV for $3f_{He}$ and 0.35 mV for $4f_{He}$ and was more intensive when pitch-angles were close to 90°. The amplitude of gyrofrequency harmonics is modulated by the rocket spin like the whistler and plasma modes and maximum of emission takes place twice during rocket spin period. Bernstein modes spectra also have thin structure and at least two maxima.

EMISSION DURING PAUSES OF ELECTRON GUN OPERATION

Some phenomena have been observed during electron injection pauses correlated with electron gun operation:

a) The pulse emission with anomalous delay for the front of the injection in the frequency ranges of plasma and whistler modes has been observed during the first part of the East flight, moreover the period of appearence of delayed pulses corresponded to that of electron gun pulsed series. This effect is more expressed in the case of plasma mode; emission during the pauses in the whistler range is rather continuous but amplitude modulated. For $\theta > 108°$ emissions were observed only for the whistler range up to the transition of electron gun to 15 keV regime. The spectrum of this emission is represented on Fig.2d.

b) Emission in the plasma mode range and in vicinity of third harmonic of electron gyrofrequency has been detected during long pauses between injection series. Emission of plasma frequency - plasma noise - (Fig.1) was continuous, modulated by rocket spin; the amplitude of plasma noise exceeded that of plasma mode pulse emission during injection by 15-20 dB. Emission near the third harmonic of gyrofrequency has been detected as a separate emission bursts occuring twice during the period of rocket spin and phase angles of emission bursts coincide with emission maxima at the third harmonic of gyrofrequency during injection. Both the plasma noise and emission on $3f_{He}$ during pauses between injection series have appeared after the electron gun was switched into operation. Plasma noise having large amplitude was being observed till the 17-th sequence of electron gun operation. Its disappearence is believed to be connected with the beginning of plasma source operation.

CONCLUSION

Reported results show the East launch to differ from the North one [1,4]. First of all it is the difference between the frequencies of maxima of whistler mode spectra; in the East launch it is higher than in the North one. Emission during pauses between injection pulses and between series of pulses should be noted. Pulsed emission during pauses may be connected with the whistler decay in the magnetospheric tube and stimulated by whistler precipitation of electrons; this processes could explain the anomalous delay. The strong influence of the rocket region enviroment is common for both launches and have been revealed in modulation by rocket spin period of all emission modes; moreover this kind of modulation is not always caused by the variation of injection pitch-angle.

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