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S-BURSTS OF JOVIAN DECAMETRIC RADIO EMISSION STORMS UNDER THE INFLUENCE OF LOW AND HIGH FREQUENCY MHD DISTURBANCES IN STREAMER-LIKE SOURCES

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ABSTRACT. There are analyzed a model for the DAM-bursts radiation by maser-cyclotron generation mechanism in the streamer-like sources that have been activated on ionization processes and MHD waves of high and low frequencies in Jupiter magnetosphere. It was accounted that the ion-atom collision processes in the magnetosphere of low-ionized plasma change the velocities and decay times of MHD waves at ultralow frequencies, because of the high and low frequency MHD disturbances have different properties and do different functions in Jupiter magnetosphere. Thus, it is shown that the typical periodicities of high frequency (HF) in S-burst-storm pattern, of about 0.5 kHz and higher 1 Hz, may be associated with HF Alfven waves, which activate the processes of DAM burst radiations. On the other hand, the typical low-frequency (LF) periodicities of S-storm radiation, of about 5 and 20 min time-scales, may be associated with LF Alfven waves, which activate the processes of plasma ionization and its stratification into streamers.

There was studied the propagation process of HF and LF MHD waves in Jupiter magnetosphere, when plasma flux is streaming inside the Io-Jupiter tube. Then, the process of maser generation of DAM bursts in presence of HF MHD-waves is investigated. We show that HF-Alfven waves perturb the electron plasma density and its velocity distribution, which give us the conditions to emit the DAM radiation effectively.

Finally, we discussed the particular properties of HF Alfven and MS wave modes in the plasma streamers, and how they form the DAM bursts, and next one, it was shown how to fit the observational data to the plasma processes that may be to work in this source model.

Keywords: DAM radio emission, bursts, MHD waves, magnetosphere inhomogeneity, Jupiter.

АНОТАЦІЯ. Проаналізовано модель випромінювання S-сплесків, в якій сплески генеруються циклотронним мазером в розшарованих на стримери джерелах, що активуються завдяки процесам іонізації та МГД хвилям високих і низьких частот в магнітосфері Юпітера.

В дослідженнях враховано, що процеси зіткнення іонів з атомами газу у магнітосфері з низько іонізованої плазми змінюють швидкості та час загасання МГД хвиль на наднизьких частотах, оскільки високо та низько частотні МГД збурення плазми мають різні властивості і виконують різні функції в магнітосфері Юпітера. Показано, що типові періодичності S-сплесків високої частоти (ВЧ), приблизно 0,5 кГц і 1 Гц, можуть бути пов'язані з ВЧ хвилями Альфвена, які активують мазерну генерацію сплесків декаметрового випромінювання. З іншого боку, типові низькочастотні (НЧ) періодичності випромінювання S-бурі, з часовою шкалою близько 5 і 20 хв, можуть бути пов'язані з НЧ хвилями Альфвена, які активують процеси іонізації плазми та її розшарування на стримери.

Досліджено процес поширення ВЧ і НЧ МГД хвиль в магнітосфері Юпітера в середині потокової трубки Іо–Юпітер, розшарованої на стримери, в яких збуджуються одночасно по декілька мод хвиль Альфвена. Та досліджено процес мазеріної генерації сплесків декаметрового випромінювання в присутності ВЧ МГД-хвиль. Показано, що ВЧ хвилі Альфвена збурюють щільність електронної плазми та розподіл швидкостей, що утворює умови задля ефективної генерації декаметрового випромінювання.

Нарешті, обговорено особливі властивості мод ВЧ і НЧ хвиль Альфвена, що існують в плазмових стримерах, та як вони формують S-сплески декаметрового випромінювання, і показано відповідності даним спостережень. Також, обговорено інші альтернативні процеси, які можуть працювати в досліджуваній моделі джерела. Зокрема, зазначено, що надтонкі ВЧ альвенівські моди можуть збуджуватися під час іонізаційного вибуху при відбитті НЧ хвиль Альфвена від верхніх шарів іоносфери Юпітера. Саме ці ВЧ альвенівські збурення керують розподілом електронної плазми в стримерах, та формують промінь декаметрового випромінювання, що повертається та спостерігається як S-сплески. Також, обговорено особливості випромінювання при утворенні пучків електронів на осі стримера, які можуть стати чинником мазерної активації S-сплесків променями із плазмових хвиль, збуджуваними на частоті біля електронного циклотронного резонансу.

Ключові слова: декаметрове радіовипромінювання, сплески, МГД хвилі, неоднорідність магнітосфери, Юпітер.

1. Introduction

Jupiter DAM radio emission is observed in the storms of duration at 1–2 hr with quasi-periodic bursts of various forms and types. The finest Jupiter bursts are S-type that has a fast-drifting structure of dynamical spectrum with duration of 2–10ms at frequency fixed and quasi-periodic separation of 5–30 ms or slower quasi-periods of 1 sec and 5–20 min. There are many DAM observations of Jupiter's radio emission since 1955, for example, the dynamical spectra of S-storms were observed by the UTR2 telescope (in Ukraine, see: Ryabov & Gerasimova, 1990; Ryabov et al., 2014) and by the Florida Radio Observatory (see FRO catalog: Flagg et al., 1991). So, in this work we take into account the typical periodicities of S-bursts that can be associated with such frequencies of MHD oscillations: $\omega_{A1..5} = 2\pi/\tau_{A1..5}$, where $\tau_{A1} \approx 0.05$ s, $\tau_{A2} \approx 0.2$ s, $\tau_{A3} \approx 1$ s, $\tau_{A4} \approx 300$ s, $\tau_{A5} \approx 20$ min.

These S-bursts are emitted by limb-sources on Jupiter's surface: Io-A,B (at S-pole Jupiter) and C (at N-pole). The Io-A,C sources are mainly associated with Jupiter's longitude meridian $\lambda_{III} \approx 180^o$, and the Io-C: $\lambda_{III} \approx 60^o$ (see: Ryabov & Gerasymova, 1990; Leblanc et al., 1993). All the bursts to be observed are mainly polarized as extraordinary X-type electromagnetic waves, and they radiate in a direction nearly perpendicular to the magnetic field lines that located at the sources in Jupiter's southern or northern hemisphere. In dynamical spectra we see the fast drifts of S-bursts, and they are superposed with the slow-drifting lanes. Typical burst drifts in the FRO catalog are *df/dt* ~ –*f*, about –20 MHz/s, which corresponds to a source moving from the surface of Jupiter at about 0.1c at an altitude of 0.1 R_j (where c is the speed of light). The drift of lanes is about 20 to 200 kHz/s. They can be interpreted as the effect of Jupiter's rotation or diffraction effects in the propagation of DAM radiation (see: Ryabov & Gerasymova, 1990). And the other way, some lanes may be associated with the source modulation by low velocity waves. In this work we analyze a model in which bursts of DAM emission are triggered by MHD waves in Jupiter's lower magnetosphere, where streamer-like inhomogeneity arises due to ionization. We assume that some lanes may be forming due to wave modulation effects, and we will study haw the S-burst generation mechanism work. This approach continues the model that was studied in the works of Boev et al. (1991, 1993) and Tsvyk (2019, 2023).

The other way, we assume now that the DAM radiation emits a burst under MHD waves in Jupiter's lower magnetosphere, in the Cyclotron Maser generation mechanism mainly. So, Hess et al. (2007) there was proposed a good and popular model for the generation of fast-drifting S-bursts in current sheets of Alfvén waves. These Alfvén waves occur during the Io–Jupiter interaction, and the electron distribution of the loss cone appears from the magnetically mirrored the electron population, leading to cyclotron maser instability (CMI, see Wu, 1985; Melrose, 1986) for X-mode bursts of EM DAM radiation. In this work we improve that model to analyze the streamer inhomogeneity of weakly ionized plasma in Jupiter's lower magnetosphere, which can be associated with ultralow-frequency Alfvén modes with a period of several minutes.

The properties of high- and low-frequency MHD waves, as well as their propagation in the Jupiter magnetosphere with gaseous matter, are studied. We take the ionization processes that allow us to form the streamer and consider how low- and high-frequency MHD waves (Alfvén and magnetosonic) are transported in the conditions of this plasma, and how CMI occurs in sheets of electron density fluctuations associated with streamer oscillations.

2. Active source model

We will analyze the source model in which S- bursts of DAM radiation are caused by MHD waves in the presence of streamer-like inhomogeneities formed in the lower magnetosphere as a result of ionization processes and MHD disturbances. This happened in Io-A,B sources that start to emit when Io tube moves over the zones of Jupiter with max-B_0 at z_j=0: $\lambda_{III} \approx 180^o$ with magnetic field is $B_{0z} \approx 14$ G, and Io-C: $\lambda_{III} \approx 60^o$ with $B_{0z} \approx 10$ G.

The effects of the Io-Jupiter interaction excite the strong Alfven-wing with the current pulses in the flux tubes as standing waves as they bounce off Jupiter's ionosphere (see, for example, Ryabov & Gerasymova, 1990). The current direction changes with periods τ_A>300 s, and this gives us a long-term modulation of Jupiter's DAM emission by Alfvén wings, which to shear the Jupiter's magnetosphere into large-scale tubes, and to start the ionization process in the lower magnetosphere in the presence of gas and flows with Io-volcanic dust.

So, the low-frequency Alfven waves, $\omega < \omega_{A4} \approx (300\text{s})^{-1}$, support a streamer formation in wave-reflected processes, and the electric E-field is activated due to the wave-current passes through the Jupiter ionosphere with v_{fx} -velocity, $E \rightarrow [\boldsymbol{v}_{fx} c^{-1} \times \boldsymbol{B}_{0z}]$ (see: Smirnov, 1995; Boev, et al. 2001; Boev, 2005). This streamer is directed nearly along to the magnetic field line or with some slope to it. The e-particle velocity distribution is anisotropic because of the flux-mirror effects, ionized plasma diffusion in the streamer; and when the MHD-oscillations maintain the cone-like electron distribution at streamer surface or accelerate an e-beam in the streamer core (see: Tsvyk, 2023).

The MHD waves properties and its velocities in weakly-ionizes plasma are varied by frequency, due to the MHD equations for low-frequency waves, $(\omega\tau_{ia})<1$, should be considered in approximation of multi-components plasma of gas mattering (see: Smirnov, 1995; Akhiezer, et al. 1974; Braginski, 1963). Therefore, as soon as the low-frequency Alfvén waves interact with the gas (of density N_a) and they velocity c_A is greatly reduce, from c_{Ai} to c_{Ag}, and these waves start the process of plasma ionization with the streamers' formation (with ion density n_i):

$$c_A \rightarrow c_{Ai} \cong B_{0z} / \sqrt{4\pi\, n_i m_p}\,,\ \omega > \tau_{ia}^{-1}\,,$$
$$c_A \rightarrow c_{Ag} \cong B_{0z} / \sqrt{4\pi\, N_a m_p}\,,\ \omega > \tau_{ia}^{-1}\,,$$

where $\tau_{ia} \cong 1/(v_{Ti}\, N_a a_\lambda^{\ 2})$, v_{Ti} is kinetic ion velocity and $a_\lambda \approx 10^{-8}$ cm is a size of H-atom.

At frequency of $\omega < \omega_{Ag} = 2\pi/\tau_{ia}$ the Alfven velocity decrease in a factor $>(n_e/N_a)^{1/2}$ because of energy dumping, running the ionization plasma processes and streamer cre-

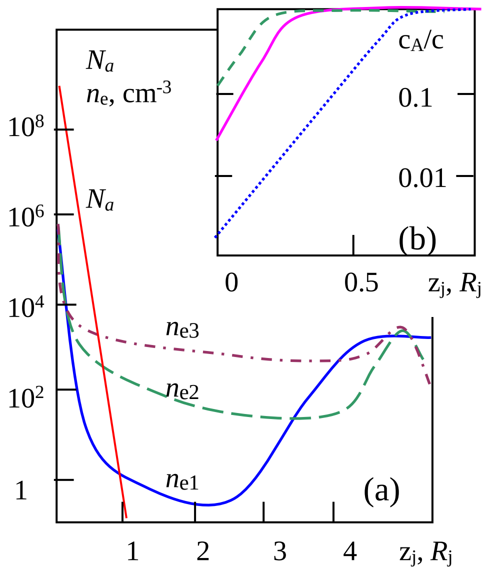

Figure 1: Plate (a) is the models for plasma n_e and gas N_a density variation at Jupiter magnetosphere altitudes z_j (in Jupiter radius units). A curve (1) is model of Su et al. (2006), (2) – Sentman, et al. (1975) and (3) – Witsers, Vogt (2017). Plate (b) is the Alfven velocity for HF ($\omega > \omega_{Ag}$), and for LF ($\omega < \omega_{Ag}$) streamer-modes variation from z_j-altitudes.

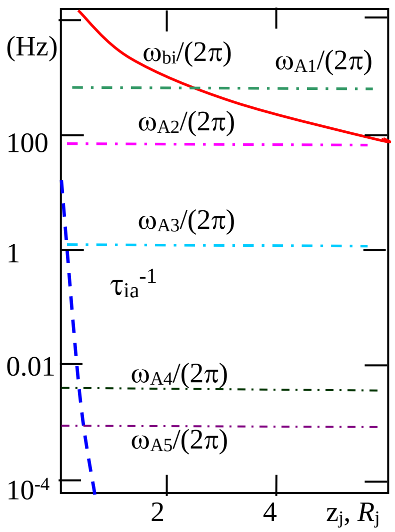

Figure 2: The ion cyclotron frequency ω_{bi} and the plasma-gas collision frequency $1/\tau_{ia}$ are varied from z_j, in compare to the typical frequencies of Alfven waves in the S-burst storm, $\omega_{A1..5}$.

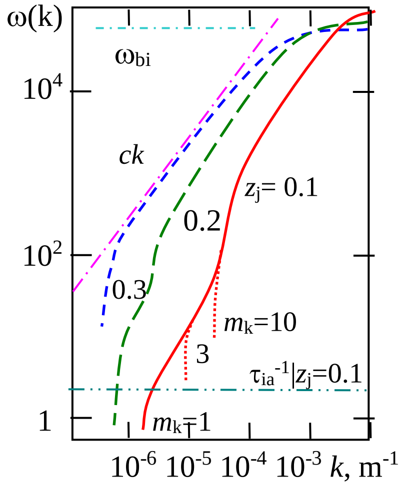

Figure 3: The typical dispersion curves $\omega_A(k)$ for Alfven modes at z_j is fixed. Here we take the streamer width a_x =200 km and $n_{e\,St}$ =20 $n_{e\,ext}$ in the model of plasma density variation by Su et al. (2006).

ation with width of a_x ~ 1/k$_{min}$. The Alfven wave energy concentrated inside the streamer $r_x < a_x$, and in this area the value of Alfven velocity is some slower then ones in external free space. And it needs to account the relativistic effect in Alfven waves transport in matter of a low-plasma density (at high magnetosphere altitudes).

3. Variation of MHD waves properties from magnetosphere altitudes

Now we consider the main properties of MHD waves in the streamer-stratified plasma when the magnetosphere altitude is varied. We take the wave deviation of the plasma parameters as a function of $\propto \exp(ik_z z + im_k\theta - i\omega t)$. These MHD waves in streamer plasma were studied, for example, in the works of Bembitov et al. (2014), Kadomtsev (1963), Tsvyk (2023). They showed that MHD waves split into modes, their properties change depending on the streamer radius direction, and the change in their properties depending on the magnetosphere altitudes will be investigated below. So, we will watch now how the speed of the Alfvén wave changes in Jupiter's magnetosphere, and consider how the magnetosphere affects the Alfvén waves at frequencies $\omega_{A1..5}$, that are corresponded to the typical quasi-periodicities of the S-spectra.

Thus, we use the models for plasma density variation in Jupiter magnetosphere, which are presented in Fig. 1. We can see on curve (1) the plasma density is much lower in the model of Su et al. (2006), and on (2,3) are slightly higher density in models of Sentman, et al. (1975) and Witsers, Vogt (2017). The fact that those models have a higher plasma density may indicate the ionization processes occurring. So, the neutral matter is present at low altitudes of Jupiter magnetosphere only (z_j<0.5 R_j); and at these altitudes we observe the occurrence of S-bursts.

The Fig. 2 shows the typical frequencies of Alfvén waves, which correspond to the quasi-periods in the S-storm $\omega_{A1..5}$ in comparison with the frequency of collisions of plasma and gas, $\omega_{Ag}=2\pi/\tau_{ia}$. And we find that $\omega_{A1..3}>\omega_{Ag}$ are mostly HF modes, and $\omega_{A4,5}<\omega_{Ag}$ are LF modes in the lower magnetosphere of Jupiter. The plate of Fig. 1,b shows us the change of the Alfven velocity from z_j-altitudes for these waves, and Fig. 3 shows us the typical dispersion curves for Alfven modes at $z_j \approx 0.1 R_j$. Here we

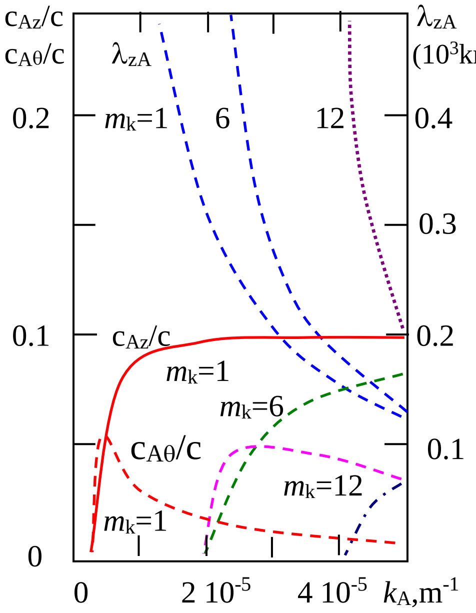

Figure 4: The velocity $c_{Az,\theta}$ of wave phase profile in z_j and θ direction from wave number k_A for m_k= 1,6,12 Alfven modes. And the wave length λ_{zA} is varied from k_A for those modes. Here is we take the streamer width of a_x=300 km at z_j=0.1 R_j altitude.

take the typical streamer width a_x ≈200 km and $n_{e\,st} \approx 10\, n_{e\,ext}$ in the model Su et al. (2006).

So, the last figure shows us that Alfvén waves can be damped strongly at low frequencies, $\omega \approx \omega_{Ag} = 2\pi\, \tau_{ia}^{-1}$, and streamer waves exist at $k > k_{min} \approx a_x^{-1}$. The dispersion curves for Alfven wave m_k-modes in the streamer are:

$$\omega(k) \cong (c_A^{-2}(k^2 - m_k{}^2 / a_x{}^2)^{-1} + \omega_{bi}^{-2})^{-2},$$

where ω_{bi} is the cyclotron ion frequency here.

The type of MHD modes that can exist in a streamer varies depending on the radius zones of the streamer, and their properties also to vary. Thus, in the streamer core there are modes of the Alfven-wave of LF (of m_k=0,1) and the electron beam is accelerated (v_b~0.1 c). Whereas in the zone $r_x \leq a_x$ there are high-frequency Alfven modes (of m_k>1 mainly) and the n_e-density fluctuation exists in current sheets. Lastly, in the zone $r_x \geq a_x$, there are exist high-frequency modes of fast magneto sonic waves (m_k = 0,1,2…) with fluctuations of ions and electron density.

4. The MHD wave modes of low frequencies

The Alfven wave modes of m_k=0 may have at low frequencies strong dumping in the streamer surface. They velocity is reduce strongly at that $k \rightarrow k_{min} \approx a_x^{-1}$ in a factor of $(n_e/N_a)^{1/2}$. That wave oscillations are: $v_{er} \approx j_r/e\, n_e$; $v_{e\theta} \approx v_{i\theta}$; $\{E_r, B_\theta\}$, and E-field strongly pumps at the streamer surface which can start the ionization process when the wave energy is high.

The Alfvén wave modes m_k = 1 can arise at about $k \rightarrow 1/a_x$ as Helical-kink modes (see Kadomtsev, 1963), and thus the waves interaction in streamer surface can convert the wave energy from mode #0 to mode m_k=1, with $k_z \ll 1/a_x$. This mode #1 can exist at the frequency ω_{A2} or ω_{A3}, as a mode with a wave-phase profile moves slowly in z-direction, $c_{Az} \sim c_A\,(k_z/k)^2 = c_A(1 - m_k^2(a_x k)^{-2})$, and the energy of MHD wave is transported at a speed c_A along the B_{0z} axis (during of τ_{A4} period from Io to Jupiter); and they gives us a good condition for the acceleration of the electron beam ($v_b \sim c_A \approx 0.1\, c$) due to the E_z wave-fluctuation in the streamer core.

The wave modes m_k > 1 exist at $r_x \approx a_x$ aria, where this wave fluctuation get a maximum value, and $k_\theta \approx m_k / a_x$. All wave modes with $m_k \geq 1$ have a phase rotation speed of $c_{A\theta} = c_A m_k (a_x k)^{-1}(1 - m_k^2 (a_x k)^{-1})^{1/2}$ which will move bunch of electron density maximum around a streamer axis. There are represented in Fig. 4 the dispersion curves of that Alfven wave modes in form of wave velocities c_{Az}, $c_{A\theta}$ that are varied from k when wave-phase is fixed, and $\lambda_z(k) \approx 2\pi / k_z$. These wave modes m_k > 1 may have dumping at low frequency $k \rightarrow k_{min} \approx m_k a_x^{-1}$ in the streamer surface, and they c_A-velocity are reduce strongly here. We have: $\lambda_z(k_{min}) \rightarrow \infty$, and a pattern of wave-phase moves slowly with fast rotation, and then goes to stop state, c_{Az}, $c_{A\theta} \rightarrow 0$. Therefore, the most likely we have LF Alfven waves' excitation (at $\omega_{A2..4}$) as the low-number modes (m_k = 1), alternatively to high frequency Alfven wave (ω_{A1}) is excited at high m_k. The other way, at high ω_A-frequency and for high k, those wave modes move along the streamer with the same velocity of $c_{Az} \sim c_A$, away from Jupiter and with slow rotation.

5. The MHD wave modes of high frequencies

The HF Alfven waves may consider for $m_k \geq 1$ modes at frequency $\omega \sim \omega_{A1,2} \gg c_A / a_x$, and they wave pattern can move at velocity of c_A or some slower. Thus, the finest Alfven fluctuation of $\omega_{A1} \approx 10^3 s^{-1}$ corresponds to the S-burst time-width, while the burst length on frequency and time corresponds to the low Alfven modes, $\omega_{A2,3}$, which overlap each other.

The finest HF-Alfven-wave modes may originate to burn as an ionization fluctuation pulse at low magnetosphere altitudes. This pulse lasts about $\tau_{e\_ioniz} < 10^{-3}$ s, when low-frequency strong Alfven wave energy reached to Jupiter ionosphere and interacted with gas (e.g., see: Smirnov, 1995; Akhiezer, 1974; Boev et al., 2001, Boev, 2005). The HF Alfven waves at $\omega_{A1..3}$ with $k_z \gg m_k/a_x$ do not interact with gas matter and here $c_{Az} \approx c_A$. Only in low z_j-altitudes of magnetosphere this condition may be changed (see Fig. 3). The other way, at frequencies of $\omega_A \rightarrow \omega_{bi}$, MHD waves (Alfven and FMS) are dumping at the ion cyclotron resonance, and Alfven waves here are transformed to kinetic modes (see Akhiezer et al., 1974; Su et al., 2006). But in Jupiter's lower magnetosphere, where we observe the S-burst sources, we have $\omega_{A1,2} < \omega_{bi}$, and only at high $z_j > 2R_j$ altitudes this ω_{bi} resonance is reached.

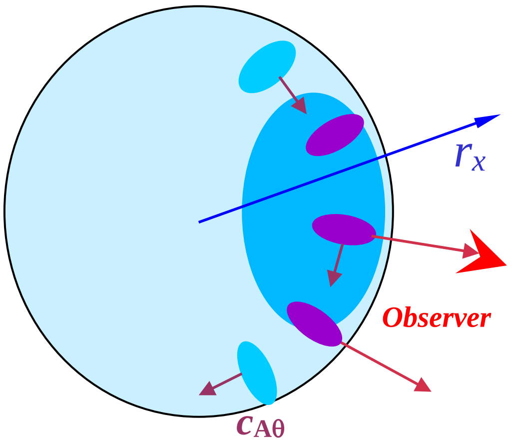

Figure 5: The sketch of the streamer for z_j is fixed, when the maximum of electron density zone is adjusted by superposition of two Alfven wave modes, m_k = (1;10), and it is rotated in θ-direction with $c_{A\theta}$ velocity, corresponding to the mode of large number (m_k = 10). This gives us the CMI radiation ray rotate direction, and get to the observer.

Thus, if we represent the pattern when a phase of Alfven wave is fixed, and correspond to the density n_e= max, this give us the wave-profile moves with c_{Az}-velocity in z_j-direction, and rotate with velocity of $c_{A\theta}$ in θ-direction, alternatively to the Alfven wave energy transports with c_A-velocity along the magnetic field lines. So, for two or more wave discrete modes may excite at the same moment (see Fig. 5). In this case, the highest ω_{A1}-frequency mode is responsible to S-burst 'width' on its time-duration. And, when this wave mode is superposed with the other m_k-modes, we have the all duration of S-burst by time and frequency that correspond to the slow and low-frequency MHD modes.

Here is represented in Fig. 5 the sketch of wave phase profile for m_k=(1;10) Alfven modes when z_j is fixed in the streamer, that is correspond to the maximum electron density zone which is adjusted by superposition of the wave phases, and it is rotated in θ- direction with $c_{A\theta}$ velocity of high frequency mode of larger number (m_k=10). In this toy model we have two Alfven modes that are exited in the streamer: the altitude $z_j \approx 0.1$ R_j, streamer width ~300km, the wave frequencies are ω_{A1} (m_1=10 mode) and ω_{A2} (m_2=1 mode); wave numbers are $k_1 \approx 10^{-4}$m^{-1} ($\lambda_{1z} \approx$60 km), $k_2 \approx 10^{-5}$m^{-1} ($\lambda_{2z} \approx$ 600km); the velocities are $c_{A1z} \approx 0.1c$, $c_{A2z} \approx 0.05c$; and the rotate oscillation times are $\tau_{A1} \approx 6$ ms, $\tau_{A2} \approx 60$ ms. We see here as the electron density bunches are rotate and move in limited zones that correspond to low-number Alfven modes. But the bunch width and they drift-speed are obtained by ω_{A1}-mode, and this way the S-bursts may radiate.

6. DAM S-burst radiation in MHD-activated magnetosphere with streamers

An unstable electron velocity distribution relatively to the cyclotron-maser instability has a form of loss-cone distribution (see: Wu, 1985; Melrose, 1986). The Maser cyclotron resonance will be got for the extraordinary (XEM) wave mode in velocity-resonance, when the velocities of the wave and the electron particle (v_z, v_x) coincide, and it has a form:

$$\omega + \frac{m_x \omega_{be}}{\Gamma(v)} - k_z v_z = 0 .$$

Here $\Gamma(v) = \left(1 - \frac{v^2}{c^2}\right)^{-1/2}$, $v = \sqrt{v_x^2 + v_z^2}$, m_x= -1, and the XEM-wave disperse curve $\omega_x(k)$ may be use a form by Ginzburg (1970) or the other approximation, that depends on the k-wave number and the electron cyclotron and a plasma frequencies, ω_{be} and ω_{pe}: $u\omega_{be}^{-2} = v\omega_{pe}^{-2} = \omega_x^{-2}$, $\omega_x^{-2} \cdot (kc)^2 \cong 1 - v(1-u)^{-1}$. The Maser cyclotron instability gives us the XEM-wave generation with an increment, which depends on the gradient on particle velocities distribution in velocities space, and θ-distribution of electrons and waves parameters to the magnetic field line.

CMI-resonance condition for XEM wave and electron velocities may be illustrated in the resonance cycles on (v_x, v_z) plates when θ and $k_z = k\cos\theta$ are fixed. Here cyclotron Maser instability arise when $df/dv > 0$ on the resonance cycle integrated. This condition realized when $kc/\omega_{be} \leq 1$ and $\theta \approx 0.4\pi$ for XEM waves, and then XEM-ray may refract within the source and $\theta \rightarrow \pi/2$. By analyze, the radiation diagram for XEM-waves may estimate as $d\omega_x/d\theta < 0$.

If we consider the fluctuation of the electron density under the influence of Alfvén waves of HF and LF modes, which have an anisotropic velocity distribution, then we will see that the fluctuations of the wave electric field control this electron anisotropy. The extraordinary EM Maser waves can be emitted inside the e-density bunches, so it gives us the rays that directed nearly to streamer perpendicular and straight into "free space". When the source-ray is turned toward the line of sight, we see these S-bursts.

When the phase profile of HF Alfven waves has a fast speed along magnetic field line, this gives us the fast drift in the S-burst frequency. In addition, the HF FMS-waves may exist at the streamer surface, and they may focus the burst ray. A picture of the burst pattern for A- and B-storms may be some different because of a streamer slope to magnetic field lines, and that way we see the multi-burst train pattern in the B-storm and the pattern with long single or long-separated S-bursts in the A-storm.

We will discuss now an additional condition for XEM burst generation. If the e-beam is accelerated within the streamer, it may be the source of plasma longitude (L) waves of $\omega \sim \omega_u \approx \omega_{be}$ by Cherenkov generation mechanism (see Boev et al., 1991). That L-ray may be to transform latter to extraordinary EM wave-ray near the streamer surface, or to supervise the XEM-wave generation at $r_x \approx a_x$ streamer areas on CMI.

The Cherenkov condition is: $\omega_l - k_z v_z = 0$,

$$\omega_l(k) \cong ((\omega_{03}^2 + c^2k^2)^{-1} + \omega_u^2)^{-1/2} - v_{Te}k.$$

The L-waves have anomaly dispersion, so they phase velocity be directed inside the streamer when the wave energy velocity directed away. The transformation L→XEM mechanism may be connected with streamer surface processes, and may be supported by FMS-wave the collision wave effect, or the linear transformation. The other way, the linear transformation may be got with induction of CMI process of S-burst generation in the streamer plasma surface with anisotropy e-distribution. And this leads to form of the bright S-burst pattern.

7. Conclusion

The LF-Alfven waves (ω_A<0.003 s^{-1}) arise due to the Io rotation and they lead to the streamer formation in $\lambda_{III} \approx 60^o$ and 180^o zones of Jupiter's lower magnetosphere with streamer width of $a_x \approx$ 20–500 km. This come to the DAM bursts generation within the streamer at the current sheets and electron density bunches on wave lengths of $\lambda_z \approx$ 10 to 5000 km.

The HF-Alfven waves (ω_A > 1 s^{-1} up to $\omega_A \approx$ 5000 s^{-1}) cause the fast-drifting electron bunches that give us the observed S-bursts. These fast S-pulses can occur when there is a burst of ionization arise due to a high-energy low-frequency (ω_A < 1 s^{-1}) Alfvén wave interacts with and reflects off Jupiter's ionosphere.

The DAM radiation may generated by Cyclotron Maser instability from bunches with cone-type electrons kinetic distribution, producing under the Alfven plasma oscillations within the streamers. In alternatively, the Cherenkov instability inside the streamer from the sub-relativistic electron beam (speed of ~0.1 c) may generate plasma waves near ω_{be}-frequency that will be transformed to XEM waves at a streamer surface, or they can be caused by the maser generation of XEM waves within the MHD-electron-bunches near the streamer surface.

Finally, we concludes that our model of Jupiter magnetosphere with streamers and Alfven waves may explain the observed S-bursts trains due to the Alfven-wave disturbance of m_k modes. And this model is some better then model of Hess-Zarka (2007) to explain the observed S-burst drifts and there sub-periodicity trains.

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