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THE DICHOTOMY OF THE MECHANISMS OF DECAMETER RADIO EMISSION FROM JUPITER: THE INFLUENCE OF STREAMER INHOMOGENEITIES AND MHD PERTURBATIONS IN THE SOURCE

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ABSTRACT. There are analyzed a model of the source of DAM radiation bursts which are activated under the MHD waves excitation in the Jupiter lower magnetosphere in a presence of ionized streamer-like inhomogeneities of limited thickness (1-100 km). There was studied the formation of an anisotropic kinetic distribution of electrons, which leads to the generation of Jupiter DAM radiation bursts under the various scenarios. It was investigated the influence of gas-dust flows in the Io-Jupiter tube, the ionization processes and the diffusion effects in the streamer plasma to the creation the cone-type kinetic distribution of electrons. On the other hand, it has been shown that Alfven waves, due to the fluctuations of electric fields, are to form of both cone-like electron distribution (primarily on the streamer periphery) and beam-like distribution with the beams of accelerated electrons (primarily inside the streamer), which further run along the streamers at speeds of about 0.1*c* and have been modulated by a "longitudinal" MHD wave with a length of about 1000 km and a period of about 1 second.

The streamer oscillations in the direction tangential to the magnetic field lines lead to the excitation the fast magneto-sonic waves (at about the ion cyclotron resonance frequencies). The beams of accelerated electrons of along the magnetic field lines generate the plasma waves in the same direction (at about the electron cyclotron resonance frequency). At the same time, plasma perturbations create a stratification of the steamer-tube structure into ultrafine threads of ionized plasma, and they contribute to the ultrafine modulation of bursts of DAM radiation with millisecond periods.

Finally, it is shown in detail how all these processes lead to activate the Jupiter DAM radiation bursts in that source at the frequency of electron cyclotron resonance by different generation mechanisms, such as the Maser Cyclotron or Cherenkov mechanisms of generation, and with different burst's properties.

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

АНОТАЦІЯ. Досліджено модель джерела декаметрового випромінювання Юпітера, яке формується в умовах збудження МГД хвиль в нижній магнітосфері Юпітера в присутності неоднорідності магнітосфери у вигляді іонізованих стимерів товщини 1-100 км. Проаналізовано механізми виникнення анізотропного кінетичного розподілення електронів, за яких виникають умови для активної генерації декаметрового випромінювання такого джерела у вигляді сплесків за різними сценаріями. Показано, що газові течії в потоковій трубці Іо – Юпітер та ефекти дифузії плазми в стримерах призводять до створення кінетичного розподілення електронів конусного типу. З іншого боку, показано, що альвенівські хвилі, завдяки коливанням електричних полів, регулюють утворення кінетичного розподілення електронів як конусного типу (переважно, на периферії стимера), так і пучкового типу (всередині стримера). В останньому випадку, виникає прискорення пучків електронів до швидкостей біля 0.1*c* (де '*c'* – швидкість світла), які надалі убігають вздовж стримерів і модулюються продольною Альвенівською хвилею з довжиною біля 1000 км і періодом біля 1 секунди.

Коливання плазми стримерів в дотичному до ліній магнітного поля Юпітера напрямку призводять до збудження швидкого магнітного звука, а прискорені пучки електронів генерують плазмові хвилі в цьому ж напрямку. Розшарована таким чином плазма стримерів формує профіль стримера з неоднорідним і анізотропним розподіленням електронів, який рухається разом з МГД хвилями зі швидкістю біля 0.001*c* і стає надалі джерелом електромагнітного ДКМ випромінювання. Відповідний рух джерела з такою швидкістю призводить до дрейфу частоти сплесків біля 0.2 МГц/сек, як і спостерігається в L-сплесках ДКМ випромінювання Юпітера. При цьому, плазмові хвилі-збурення створюють розшарування стимера на тонкі нитки іонізованої електронної плазми, та сприяють надтонкій модуляції електромагнітних сплесків ДКМ випромінюваня, як в S- сплесках.

Всі ці процеси сприяють генерації ДКМ випромінювання Юпітера у вигляді L- та S- сплесків, та відповідають різним сценаріям і механізмам генерації випромінювання. Зокрема, L- сплески можуть бути пов'язані з Мазерним випромінюванням активної плазми джерела на периферії стимерів, яка активується швидкими МГД хвилями, а S- сплески можуть бути пов'язані з Черенковським випромінюванням швидких пучків електронів, яке збуджується першочергово і переважно в вигляді плазмових хвиль в джерелах всередині стримерів, та перетворюється надалі в спостережуване електромагнітне радіо випромінювання сплесків.

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

1. Introduction: the observed properties of Jupiter DAM radio emission

Jupiter is the brightest planet of the DAM radio emission, which power gives up to 10^7Jy in bursts (see: Ryabov & Gerasymova, 1990, Ryabov, et al., 2014). The dynamical spectrum of the Jupiter's bursts are observed of various forms and types, and the main of that types are long (L) and short (S) bursts in Jupiter DAM radiation, that have burst-variation by frequency and time. So, the L bursts lasts of 0.3-5 s, and that bursts have the frequency drift of ~200 kHz/s, which may correspondent to move of this source velocity by about 0.001*c* (where *c* is the light velocity). The S bursts lasts of 0.002-0.03 s, and they have the fast drift of a burst frequency, ~20 MHz/s, that correspondent to the fast source velocity up to 0.1*c* (see: Ryabov, Zarka, et al., 2014, Boev, et al., 1993, Tsvyk, 2019). All the bursts are observed as the extra ordinary X-type polarized EM waves, and there are radiated in the direction of near perpendicular to the magnetic fields lines at the sources in the southern or northern Jupiter hemisphere.

The Jupiter's bursts are connected with the generation mechanisms which work with the anisotropic electron distribution in the source (see: Wu, 1985, Melrose, 1986, Ryabov & Gerasymova, 1990, Boev & Luk'yanov, 1991). So, it may be the Maser cyclotron instability with cone-like anisotropic electron distribution, $f(v_{e\perp}) \gg f(v_{e\|})$, or the Cherenkov instability of plasma wave in the presents of the electron beams with the electron distribution of $f(v_{e\perp}) \ll f(v_{e\|})$. The last way of a burst radiation must have the wave transformation processes, where the plasma wave is converted to the EM wave by resonance wave-coupling process, or by the linear conversion that came in the density-inhomogeneous plasma (see: Boev & Luk'yanov, 1991, Boev, et al., 1993).

In this report, we are represented and analyzed a model for the source of the DAM radiation that activated the burst under the MHD waves in the presence of ionized streamer-like inhomogeneities in the lower magnetosphere of Jupiter, in different generation mechanisms. The further, by the way, we are to study the dichotomy of Jupiter DAM radio emission that differ to the Maser Cyclotron or Cherenkov mechanisms of generation.

2. The model of an active source and the main processes

We will be investigated the processes in the gas-dust flux tube such as the ionization process by streamer-like structures, the plasma diffusing processes, and the MHD waves of streamer oscillations, and the last one the process of the EM wave emission by Maser Cyclotron or Cherenkov radiation mechanisms. There are analyzed a model of the source that give us the DAM radiation bursts which activated by the MHD waves in the presence of the ionized streamer-like inhomogeneities that was formed in the lower Jupiter magnetosphere.

It is the well-known effects of the Satellite-Jupiter interaction, which excites us the strong Alfven-wing with the current pulses in the Io-Jupiter flux tubes and others as the standing waves (see, for example, Ryabov & Gerasymova, 1990). The current direction change with 300-seconds-period, and it give us the 300-seconds-modulation in Jupiter sporadic DAM radiation by Alfven-wings, that corresponds to the shearing the Jupiter magnetosphere to the large-scale flux-tubes of about 1000 km diameters. The streamer which we will be considered now is not that wing-tube structures, but they are the more fine structures inside of these tubes.

In even and other of that wing-tubes, the gas particles (ions, gas atoms and dust) move nearly along the magnetic lines and fall to the Jupiter. The thermal and electric interaction of volcanic dust with stones, and with the low-ionized plasma and gas, that have been ones injected by Io (or by Sun, or by another Jupiter satellite), will be created the ionized streamer in the form of the plasma streamer-tubes of width of about a_x~ 100 km, that is much shorter then width of the main Io-Jupiter flux tube.

The streamer plasma may creates by Saha-Langmuir electron ionization mechanisms (see: Smirnov, 1995, Boev, et al. 2001), that comes when the gravity-accelerated dust-stone fluids is interacted with gas matter (n_a) and have heat the plasma high then 4000 K:

$$n_e^{\,2}/(n_a - n_e) \propto Const \cdot T_e^{\,3/2} \cdot \exp(-\varepsilon / k_b T_e) \,.$$

In Jupiter magnetosphere we have T_a<1000K (for gas matter), T_e~3000K (for electron matter) (see: Boev, et al., 2001). The streamer plasma is some more hitting, pinch-compressed and stratified matter, and the streamer structure may be justified by observations when we observe the different frequency drifts of DAM bursts in dynamical spectra.

There may be run the next plasma processes in that streamer-stratified plasma: the ionization; the streamer-pinching processes; the adiabatic effects in the streamer flows; the plasma-rain processes; the coupling of the streamers (by the current flows coupling or in the magnetic field reconnection processes); the streamer MHD-wave excitations (see latter); the streamer stratification effects; the plasma diffusing out the streamer (with ambipolar flow).

So, the pinching effects are supported the streamer formation, because of the plasma compression by the j_z-pinching effects or by the j_θ-pinching effects (see: Kadomtsev, 1963, 1988). The first way, the current of $j_z(r_x)$ are supported the streamer magnetic field to grow as $\mathbf{B} \sim (\mathbf{B}_{0z}+\mathbf{B}_\theta)$, and this leads to the localization of a streamer matter within its flux tube. The next one is the j_θ-pinching effects, when the current of $j_\theta(r_x)$ will take place at the streamer stabilization processes with the added of an longitude streamer magnetic field of the value dB_z. In additionally, the geometry of the streamer is anisotropic, due to the fact that the magnetic field lines B_{0z} converge and the width of the streamer decreases towards the surface of

Jupiter (at low z_j), and therefore the transverse electron velocities in the fluxes and their distribution change adiabatically as: $\frac{{v_{e\_|\_}}^2}{B_{0z}(z_j)} = Const$ (Kadomtsev, 1963). All of these effects support the formation of a 'static' streamer structure, and the other way, the streamer plasma diffusion both and the fluxes geometry effects are leading to the anisotropization of the electron distribution, and the fluctuation of pinching current leads to the dynamical effects by the MHD waves excitation.

The further in the section 3 we will study on the MHD-wave excitations effects in detail, because of it leads to the pumping dynamically of the anisotropic electron distributions, and then, that give us the arising the EM bursts waves radiation in different ways, and it may explain us the formation of the Jupiter DAM bursts (in the section 4).

3. The features of MHD waves inside the streamer

Here we are studied how the MHD waves are excited and transported in the streamers along or in transverse directions to the magnetic field lines, in using the basic theory of MHD hydrodynamic, see: Kadomtsev (1963), Akhiezer (1974). The next study is how these waves can affect to the kinetic distribution of electrons through fluctuations in electric fields, and we will see these effects too.

The MHD waves in the streamer matter need to see in 3D-geometry (like to the Sun streamer study, see: Appert, et al., 1974, Edwin & Roberts, 1983), and in the MHD equations there must be account the low-ionized plasma conditions of multi-components fluids (electron, protons/ions and neutral gas atoms) (see: Braginskyi, 1963). So, that way the equations of moving fluids in the low frequency, for Alfven and fast magneto-sonic waves, will have the main term in that accounted the neutral gas inertia, and the Alfven wave velocity will dependent not from ion density (n_i~n_e), but from the neutral gas density (n_a, when n_a >>n_e), that give us the much slowly Aflven velocity then in the classic case:

$$c_{A\_gas} = \sqrt{B_{0z}/(4\pi n_a m_p)} = c_{Ai}\sqrt{n_i/n_a} .$$

And then, in high frequency, the fast MHD wave velocity grows up to the c_{Ai} value.

At this reason, in Jupiter magnetosphere it may realize some cases on the MHD wave velocities and its dispersion. At first, the fast MHD wave velocity in low-ionized plasma depends on the degree of ionization and on the wave frequency. So, in the streamer, c_A velocity at a large wavelength (small k_A) not varied in streamer width, because of c_A~c_{A_gas}, and because that the MHD waves not be dumping strongly. The wave field values, B_w, E, both and the current density fluctuation values, j, n_{wi}, v_i, v_{we} , are dependent on the streamer width coordinates, r_x, and they be limited by streamer width r_x~a_x, because of variations of a plasma density, $n_{i0}(r_x)$.

There are considered now the main properties of the 3D-MHD waves in the in streamer-stratified plasma. We take the wave deviation of the plasma parameters as a function of $\propto Fct(r,\theta)\cdot\exp(ik_z z + im_k\theta - i\omega t)$. These streamer waves ware studied (for example) by Edwin& Roberts (1983), Bembitov, et al. (2014) in solar plasma conditions, but now we will look for E-fields and electron wave velocity oscillations which can be found by using Maxwell's and MHD wave equations at Akhiezer (1974).

Let us begin to consider from Alfven waves properties in the {z, r_x, θ}-geometry, which will be mainly propagate along the magnetic lines with $\mathbf{k_A} = (k_{zA}, k_{rA}(m_k)\}$~$\mathbf{k_{zA}}$. That waves may be excited at the resonance frequency in the helical mode (m_k=1) with ω_{res}<<ω_{Bi}, by the Helical instability (see Kadomtsev, 1963), where:

$$\omega_{A(Hel)} \cong c_A \cos\theta\,(1 + \left(k_{zA} - \frac{m_k b_\theta}{a_x}\right)^2 - \frac{m_k {b_\theta}^2}{{a_x}^2})^{1/2}$$

Here is: $b_\theta = B_{\theta A}/B_{z0}$. In the Jupiter magnetosphere conditions, this Helical-kink Alfven mode (m_k=1) are running along the magnetic field lines, with the $\lambda_{A,z}$ -lengths that are high then streamer width (a_x), and it will be compared 3000km, that is high-scales of Jupiter magnetosphere at low z_j-altitudes. That wave frequency is about ω_{res} ~1 s^{-1} (ω_{res}<<ω_{Bi}), and resonance Alfven wave length is $\lambda_{A,res}$ ~ $2a_x/b_\theta$ ~ 1000km, when the streamer width is a_x~1-100 km.

It should be note that the parameters of that 3D Alfven waves are limited by the thickness of the streamer, and maximum of Alfven wave frequency ω_{Bi} goes down outside the streamer. There are no wave density fluctuations by time, alternatively, we have the static plasma density dependence in the streamer, $n_{i0}(r_x)$. The magnetic field and electric fluctuations in the Alfven waves are connected with j_z-pinching oscillation, and they have $B_\theta(r_x)$, $E_z(r_x)$, $E_r(r_x)$ components. Because of the streamer cylindrical geometry, the r_x-dependence of the field components comes to zero in the streamer core, $B_\theta(0) = E_r(0) = 0$; but $E_z(0)$ field in the streamer core is a big value. Out in the streamer core, the Alfven waves have the plasma (ion and electron) particle fluctuations in the θ–direction mainly with $v_{e\theta}(r_x)$~$v_{i\theta}(r_x)$, where $\mathbf{v_e} = \mathbf{v_i} - \mathbf{j}/(en_e)$; and they have a non-zero current fluctuations $j_{er}(r_x)$, $j_{ez}(r_x)$, and an electron velocity is differ then ion ones in z_j- and r_x- directions, $v_{ez,r}(r_x) \gg v_{iz,r}(r_x)$. Because of the streamer geometry, the r_x-dependence of current and transverse velocity components comes to zero in the streamer core, $j_{r,\theta}(0)$→0 and $v_{e\_|\_}(0) = (v_{er}^2(0) + v_{e\theta}^2(0))^{1/2}$→0. Alternatively, we have non-zero z-component of electron velocity, $v_{ez}(0)$, in the streamer core, and that sketch of electron velocity distribution within the streamer have been represented in Fig. 1.

The electric field oscillations in the Alfven wave lead to the pumping of the electron kinetic distribution of various types inside and outside the steamer core. Thus, the electrons swing with velocity $\mathbf{v_e}$ along the streamer and is accelerated inside the streamer core to the high-velocity electron beam, up to $v_{e\,beam}$~c_{Ai}~$0.1c$. Alternatively, in the streamer periphery, the transverse velocities $v_{er,\theta}(r_x)$ of much number of electrons are raised dynamically, and we have to pumping the cone-like electron distribution in that place.

The next type of MHD waves that may be interested in the 'streamerring' Jupiter magnetosphere is the fast magneto-sonic (FMS, or Helicon) waves. Those waves may be generated partly at the deep streamer core as the waves which propagate along the magnetic field lines in added to the Alfven waves of low-frequency fluctuations (λ_{ms_x}),

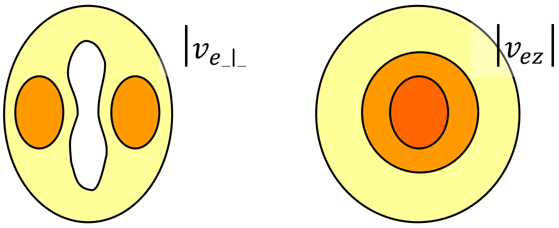

Figure 1: The sketch of the streamer at z_j=const, which show the v_e-electron velocity fluctuations in the case of Alfven wave have been excited. Thus, the electrons are accelerated inside the streamer core to the electron beam because of v_{ez} oscillations, and there are pumping the cone-like distributions in the streamer border because of $v_{e\_|\_}$ oscillations.

when the wave-energy is partly converted from Alfven type to the FMS waves. The other way, the fast magnetosonic waves will be exited in the perpendicular direction to the magnetic field line mainly due to the plasma diffusion processes in the streamer periphery places, as the small-size magneto-sonic waves at high frequency of about ion-cyclotron and up to "plasma cyclotron hybrid" frequency. The fast magneto-sonic waves have a view a sausage radial fluctuation at $\mathbf{k}=\{k_z,k_r\}$, or a kink-surface streamer mode (m_k=1,2..) at $\mathbf{k}=\{k_z,k_\theta\}$ on e-plasma density profile. The fast magneto-sonic turbulence may lead to the fast plasma diffusion and to the streamer stratification. The pinching effects are "joining" the plasma in the streamer frame, to interrupt the plasma diffusion and plasma stratification processes.

The magnetic and electric field fluctuations in the FMS waves are connected with the j_θ -pinching oscillation and they have $B_z(r_x)$, $B_r(r_x)$, $E_\theta(r_x)$ field components. Because of the streamer cylindrical geometry, the field components comes to zero at a streamer core, $B_r(0) = E_\theta(0) = 0$. These fast MS-waves have the main plasma (ions, electrons) particle fluctuation in the r_x- and θ-direction with $v_{ir}(r_x){\sim}v_{er}(r_x)$, and they have an electron and current fluctuations in θ- direction: $v_{e\theta}$, $j_\theta(r_x)$. Thus, under the fast MS-waves influence, the transverse velocities $v_{er,\theta}$ of number of electrons are raised dynamically in the streamer periphery, and this way the cone-like type of an electron distribution are pumping at the streamer border.

Finally, we stop briefly at the low MS waves and at the plasma waves inside the streamer. So, the low MS waves may be exited in the streamer at the low-frequency sausage modes which have the plasma density fluctuation v_i in z-direction mainly, and this wave is transported along the streamer. It is very slow mowing wave, because c_s/c_A<0.0001, and it be exist when the electron temperature be higher than ion ones. The magnetic oscillations in these waves are small, so the electric field oscillations are potentially and have the components E_z, E_r which connects with the current oscillations, $j_{z,r}$. So, the electron oscillations in this wave will have $v_{ez} \gg v_{er}$, $v_{ez} \leq v_{iz}$, and they may lightly support the injection process of electron beam together with Alfven waves, but not give us of high velocity of beam which we observed.

The beam, that have arisen inside the streamers core, will generate the plasma waves in Cherenkov instability at nearly the electron Debye wave-lengths, $\lambda_l{\sim}{k_{De}}^{-1}{\sim}v_{Te}/\omega_{pe}$, and at the frequency $\omega_l \sim \omega_u = ({\omega_{be}}^2 + {\omega_{pe}}^2)^{1/2}$. This plasma wave has an electron density, velocity and current oscillations, $n_e(r_x)$,$v_{e\theta,r}(r_x)$, $j_{r,\theta}(r_x)$, and the ion wave oscillations are extremely small. Electric and magnetic fields in the plasma wave are the circular polarization modes, and the E-field component transforms to the longitude fields E_z at frequency up to the upper hybrid resonance, ω_u. Plasma wave velocities at high frequencies have characteristics of anomalous dispersion waves, and it transports the energy out the streamer when the wave velocity directed inside the streamer. The wave polarization change at the frequency, in which the plasma wave comes to anomaly dispersion region.

4. The influence of MHD waves on the EM bursts radiation

The electron kinetic distribution in the streamer-like magnetosphere may change by adiabatic effects in the magnetic flux $B_z(z_j)$ -tubes of in the gas-dust Io-Jupiter flows, or by plasma diffusion in the streamer structures, or by pumping effects at the electro-magnetic forces of MHD waves influence. So, that is way will be formed mainly the cone-type kinetic distribution of electrons for first of two cases. Alternatively, under MHD waves, the fluctuations of electric field depended on the site place in the streamer, and it changed on the MHD wave length and period.

Thus, due to the MHD wave oscillations, the kind of the kinetic electron distribution is varied by streamer radius as that the cone-like electron distribution form at medium and high speeds, primarily on the streamer periphery, and to the beam-like electron distributions form with an electron beam of that have been accelerated to speeds of about $0.1c$ in the streamer core. This leads to the dichotomy of DAM bursts that connected with activation the EM waves by MHD waves of different types.

Here is we consider how the EM waves radiate in the bursts in the sources (see: Wu, 1985, Melrose, 1986, Ryabov & Gerasymova, 1990, Boev & Luk'yanov, 1991). The EM waves are generated when it defined that resonance condition in electron velocity:

$$\omega + \frac{m_k \omega_{Be}}{\Gamma(v_e)} - k_z v_{ez} = 0 \ ,$$

where it is $\Gamma(v_e) = (1 - {v_e}^2/c^2)^{-1/2}$, and this give us the EM burst be excited by two ways: for $m_k = -1$ (one way) when it is generated the Maser DAM radiation (X-EM), and for $m_k = 0$ (second way) when radiation comes in the plasma waves that will transform further to the DAM radiation (of X-EM mode). So, when the condition for the burst generation has been realized, the bursts radiate. The type of generation mechanism depends on the e-particles distribution, and the Maser mechanism works in the places where is the cone-like kinetic electron distribution realized in the source, alternatively, Cherenkov radiation corresponds to the places with the beam-like electron distribution.

Here is the Alfven wave deviate the kinetic velocities distribution in scratch profile $f\{v_e; z_j, r_x, \theta; t\}$ that move with c_A velocity along the Jupiter magnetic field lines. This is give us to observe the slow drift of the frequency of the bursts radiation in the frequency-time dynamical spectra df/dt ~200 kHz/s, and this drift can be seen in the L-bursts.

Let us consider how to form the short (S) and narrow (N) bursts of the Jupiter radiation. One way, they may radiate by the short FMS waves (λ_{ms}~0.1-1 km) that modulate the streamer border surface, so, it may be give us to observe the fast-drift of the EM radiation which varied in (*f*-*t*) spectra. And, the second way, in the case of when the electron beams are running in the streamer core strongly along the magnetic field lines with the velocity up to v_{ez}~$0.1c$, and this may excite the Cherenkov generation of Plasma waves, and it give us the second way of S-burst radiation with the frequency drift of df/dt ~ 20 MHz/s. So, in variation the plasma density in the streamer may give us the finest burst profiles with splitting and other features.

Finally, we have show that all these processes lead to the activation of the bursts of Jupiter's DAM radiation in that source at the frequency close to the electron cyclotron resonance, with different generation mechanisms and with different bursts properties.

5. Conclusion

The streamer-like structure, that arise by ionization process in Jupiter magnetosphere, supports the anisotropization of kinetic electrons of both as cone-type and beam-type distributions, that further leads us to the generation of Jupiter's DAM burst radiation under different scenarios. The cone-type kinetic distribution of electrons arise under adiabatic and diffusion effects, and under the influence of the MHD waves, due to the fluctuations of wave electric field. That way we have the streamer to be an effective source to DAM radiation by Maser generation mechanism, that be changed dynamically.

The Alfven waves move along the streamer and pump the electron distributions of both "cone-like" (primarily on the streamer periphery) and "beam-like" type of accelerated electrons (with the electron beam speeds of about $0.1c$, in the streamer core). These Alfven waves have lengths of about ~ 1000 km and periods of ~ 1 second. The streamer's fast magneto sonic waves (of short-lengths and moving in out or tangential to streamer direction) also support the "cone" electron distribution, and may modulate of DAM bursts.

The beams of accelerated electrons, that can arise in the streamer core, will generate the plasma waves in the tangential to streamer direction (at about the electron cyclotron resonance frequency). This wave radiation will be converted to EM mode and may give us to see the fast-moved (S) bursts of DAM radiation.

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