Chapter 5

Parametric Decay Instability

5.1 A Review:

When wave of large amplitude perturbs a plasma system, it can couple the other modes and some of the wave energy is converted to other forms of wave motion. The study of parametric decay instability is very important because of its role in anomalous heating of plasma, lower resonance heating etc. Although various techniques are used for heating of plasma in tokamaks and stellarators, such as ohmic heating, transit time magnetic pumping (TTMP), these have many disadvantages. For example, ohmic heating cannot raise the plasma temperature to the desired value of ten kilo electron volts because of the fact that electron ion collision frequency rapidly decreases with electron temperature. Hence, additional heating with the help of nonohmic process such as anomalous absorption due to parametric process can give the additional heating.

The term ‘parametric Excitation’ is used to represent those nonlinear phenomena, where the parametric effect is due to the variation of the parameter with a double frequency. In plasma, when a wave of large amplitude perturbs a plasma, it can couple to other modes. Some of the wave energy is con-
verted to other forms of wave motion. If a high intensity, externally driven wave with frequency $\omega_0$, passes through plasma that has an existing mode of oscillation at $\omega_1$, beats occur with the wave at $\omega_0$ and sidebands are generated at $\omega_2 = \omega_0 - \omega_1$ and at $\omega_3 = \omega_0 + \omega_1$. If $\omega_2$ is another lightly damped plasma mode, it will now beat with $\omega_0$ at $\omega_1 = \omega_0 - \omega_2$ and at $\omega_4 = \omega_0 + \omega_2$. If $\omega_2$. Thus, the mode at $\omega_1$ is enhanced, and will beat more strongly with $\omega_0$ to give a stronger $\omega_2$ mode. The physical parametric excitation can be considered as a nonlinear instability of two waves ($\omega_1$ and $\omega_2$) by a modulating pump wave ($\omega_0$) due to mode coupling interaction. The resonance condition for three-wave interaction involving parametric process are:

$$\omega_0 = \omega_2 \pm \omega_1 k_0 = k \pm k_1.$$

If a pump wave of frequency $\omega_0$ and wave vector $k_0$ is launched into a collisionless plasma such that its wavelength is very large (small $k_0$), its phase velocity may be more than the electron thermal speed and the mode will be undamped. If there is low frequency perturbation ($\omega, k$) in the plasma, such that $\omega << \omega_0$ and $k >> k_0$, it will nonlinearly interact with the pump wave leading to the generation of sideband components at $\omega \pm \omega_0 \approx \omega_0$ and $k \pm k_0 \approx k$ which will have a considerably smaller phase velocity viz. $\omega/k$. When the pump wave frequency is close to one of the natural frequencies of the plasma, say a lower hybrid frequency, it drives the natural oscillations resonantly and their amplitudes become quite large.

The large-amplitude side-band modes are heavily damped by Landau damping because of their low phase velocity. Thus, the pump wave after decaying into other modes, gets absorbed in the plasma. This is known as anomalous absorption of the pump wave leading to anomalous heating of the plasma. It is easy to get high power with waves of low frequency. Hence lower-hybrid resonance heating has been paid more attention for anomalous heating of fusion devices. Kindel et al [1972], from their theoretical study, predicted for the first time the parametric instability and heating of electrons and ions by lower hybrid pump.
Porkolab [1974] has studied about the coupling of a low frequency ion mode with frequency \( \omega < \omega_{pi} \) to a relatively high frequency electron mode due to the presence of an RF electric field \( \omega_0 \) in the plasma. They have discussed the possibility of parametric instabilities in RF heating experiments and surveyed the experimental evidence for the occurrence of parametric instabilities and associated anomalous absorption or heating. Chang and Porkolab [1974] have reported experimental observations of a new type of parametric instability which involves the excitation of lower hybrid waves and non-resonant low frequency ion quasi modes when the pump RF field is near the lower hybrid frequency. The non-resonant frequency is found to be the dominant one for pump frequencies between 1 to 3 times the lower hybrid frequency. Satya et al. [1974] have shown that a long wave length oscillation electric field at lower-hybrid frequency can be anomalously absorbed in a plasma with short wavelength low frequency fluctuations because of their coupling to short wavelength are damped.

It is already mentioned that parametric decay of wave with frequency near the lower-hybrid wave is very important for the heating of plasma in fusion devices. Stix et al. [1965] has given the theory of linear conversion process around the lower-hybrid frequency. They showed that along wavelength EM wave at the LHD wave frequency can be linearly converted into short wavelength ES, modes which can get heavily absorbed by linear Landau damping. The lower-hybrid resonance occurs, depending upon plasma parameters at a frequency \( \omega \), such that \( \omega_{ci} < \omega < \omega_{ce} \). Because of resonance between the phase velocity of the wave and thermal velocity of the ions, absorption of the waves by the ions is possible. The magnetic field has a weak effect on the ions, but it strongly limits the motion of the electron perpendicular to the field. Above certain incident threshold power values, the incoming wave may decay spontaneously into two daughter waves, by the process of parametric decay. The daughter waves can be ion waves, which are highly damped, and give rise
to high heating rates in the plasma.

In the next section, parametric decay of lower-hybrid wave into ion-cyclotron and dust-acoustic wave is investigated. Using fluid equations for the plasma species viz. electrons, ions and negatively charged dust grains, dispersion relation is found out. Finally, the growth rate is calculated and the effect of pump wave frequency and electric field on growth-rate is investigated in ionospheric plasma.


5.2 Parametric Decay of Lower-hybrid Wave into Ion-cyclotron Wave and Dust-acoustic Wave

Parametric decay instability of lower-hybrid pump wave with frequency $\omega_0$ is considered in a dusty plasma. Nonresonant decay takes place to high-frequency ion-cyclotron and low frequency dust-acoustic waves under suitable condition. Growth-rate of the instability is calculated and plotted against the lower-hybrid pump frequency for ionospheric data. The process may play an important role in ionospheric heating.

5.2.1 Introduction:

The study of dusty plasma has become quite important these days because of its presence in various space environments like planetary rings, cometary tails, lower ionosphere of earth as well as laboratory plasma including fusion devices. Stress has been given in studying collective waves in dusty plasma in recent years. A new type of sound wave, viz. dust-acoustic wave can emerge on a very slow time scale of dust dynamics as a result of the balance between dust grain inertia and plasma pressure. Presence of charges dust component leads to the appearance of new plasma modes arising from the dust grain dynamics.

Parametric decay instability of lower-hybrid wave is considered to be very important because it plays a major role in anomalous heating of plasma, such as lower-hybrid resonance heating. Lower-hybrid waves propagating nearly orthogonal to the magnetic field are widely applied in controlled nuclear fusion research for plasma heating and current drive. In most of the fusion devices, ohmic heating can hardly serve the purpose of raising the plasma temperature to the desired temperature level. Anomalous absorption due to parametric process might be used for providing the additional heating.
Porkolab has studied the coupling of a low frequency ion mode with frequency $\omega < \omega_{\text{pe}}$, to a relatively high frequency electron mode due to the presence of an rf electric field $\omega_0$ in the plasma. It is seen that electrostatic plasma waves may become unstable in such a situation, the energy being provided by the external electromagnetic field. The possibility of using parametric instability in anomalous absorption or heating of plasma is investigated. Sharma et al [1984] have given the theory on the parametric decay of an ordinary electromagnetic wave into an upper-hybrid wave and an electron acoustic wave. They have shown that electron acoustic waves can easily be excited by parametric process in a nonisothermal plasma. Kumar et al [1995] have calculated the growth rate for parametric decay instability of an extraordinary electromagnetic wave into an electron Bernstein and electrostatic whistler waves and have pointed out the relevance of the process to explain the generation of whistler mode radiations in the SL-2 experiment, ionospheric modification experiment, electron cyclotron resonance heating in the MTX tokamak etc. Recently, Sharma et al [1984] examines the decay instability of the X-wave into EBW and ion Bernstein wave using kinetic theory and including the finite Larmor radius effects with the relevance to ionospheric modification experiments, as well as MTX parameters.

The rf-heating of tokamak plasmas with pump frequency near the lower-hybrid frequency has been widely studied. Ions are heated by the pump in this frequency range through nonlinear Landau damping and through excitation of parametric instabilities which, in turn, gives rise to anomalous heating of ions. Porkolab [1974] has found that for homogeneous pump, the decay into lower-hybrid waves and ion-acoustic quasi modes is allowed, and analyzed this decay process by solving Vlasov equation. Berger and Perkins [1976] have studied parametric decay of lower-hybrid wave (with finite $k_0$) into three channels viz. lower-hybrid and ion-acoustic waves, lower-hybrid and ion-cyclotron waves and lower-hybrid and Bernstein waves using fluid theory. They have shown that the
lowest threshold correspond to decay into lower-hybrid waves and backward ion-cyclotron waves and ion-acoustic waves in the dipole approximation for the pump wave. For larger pump powers, the nonresonant decay process i.e. quasi-modes are found to have larger growth rates. Tripathi et al. [1977] have given a unified theory of parametric instabilities in the lower-hybrid frequency region using drift kinetic equation for electrons and Vlasov equation for unmagnetized ions. They have shown that the pump wave around the lower-hybrid frequency, the dominant channel of decay is through ion-acoustic and lower-hybrid waves when $T_e/2T_i > 4$ and through lower-hybrid wave lower-hybrid quasi-mode when $T_e/2T_i \leq 4$.

Glagolev et al [1971] have reported about the experimental evidence of ion and electron heating at a frequency near lower-hybrid resonance. Hooke and Bernabei have observed parametric instability at frequencies close to and above the lower-hybrid resonance frequency. Kindel et al. [1972] have predicted theoretically and observed in numerical simulation experiments a parametric instability which leads to ion and electron heating. Thus, parametric process is widely studied because of its importance in radio-frequency heating and plugging, feedback control in pinch mirror devices.

Although elaborate study has been done on parametric instability in plasma, little attention has been given to the study of parametric instability in dusty plasma. In space plasmas, such as earth's lower ionospheric regions, planetary ring systems, cometary tails, asteroid zones etc., dust particles are immersed and get charged to an electrostatic potential determined by a balance between charge collection from the plasma and charged particle emission and field emission. Rao et al [1990] have studied long-wavelength, low frequency collective oscillations in a dusty plasma. It is important to study parametric instability in plasma in presence of charged dust grains.

In this paper we have investigated parametric decay instability of lower-hybrid wave into ion-cyclotron and dust-acoustic waves. A current carrying
dusty plasma is unstable to ion-cyclotron waves. When a high power radio wave in the range of lower-hybrid frequency is launched into plasma, it may decay to ion-cyclotron and low frequency dust-acoustic wave. We have considered a homogeneous magnetized plasma containing electrons, ions and dust particles of constant charge with magnetic field \( \vec{B}_0 \) along z-direction. The pump wave near the lower-hybrid resonance frequency \( \omega_0 \) is propagating in the x-z plane almost perpendicular to the magnetic field \( \vec{B} = B_0 \hat{z} \). We have investigated the resonant decay of this lower-hybrid pump wave into ion-cyclotron and dust-acoustic waves by calculating the growth rate for the decay.

Throughout our discussion, dust charge has been taken as constant. In the regime \( a \ll d \ll \lambda_D \), where \( a \) is the grain radius, \( d \equiv n_d^{-1/3} \), (\( n_d \rightarrow \) grain density) and \( \lambda_D \) is Debye length, the charged dust may be considered to be massive charged point particles, similar to multiply charged negative or positive ions, except the fact that dust can have much larger mass and charge. The regime \( d \ll \lambda_D \) is obtained in various cosmic dusty plasma environments such as interstellar clouds, the earth's ionosphere (at \( \sim 80Km \)) planetary rings [Rosenberg 1993]. The properties of waves in dusty plasma have been widely studied in recent years. In this problem while discussing parametric instability of LHD wave in dusty plasma, dust grains have been considered as having constant charge which is valid in the regime \( a \ll d \ll \lambda_D \) as discussed above. Heating of ionospheric plasma has been discussed from a long time. The phenomenon of decay of LHD wave to ion-cyclotron and dust-acoustic wave may give proper explanation to the problem of ionospheric heating.

Study of parametric decay of LHD wave excitation is important both from astrophysical as well as laboratory plasma point of view. LHD wave is found to be effective in accelerating electrons parallel to the magnetic field and producing high energy trails in the electron distribution function. Morales and Lee studied the nonlinear propagation of LHD waves in a homogenous plasma.
in a two dimensional situation. They found that the nonlinear interaction of the LHD waves with slow plasma motion produces large density perturbations. The latter in turn modify the character of pump wave.

5.2.2 Theoretical Formulation:

We consider a homogenous magnetized plasma containing electrons, ions and constant charged dust particles. The magnetic field is along the z-direction. The low-re-hybrid wave is propagating in the x-z plane, almost perpendicular to the magnetic field $\vec{B} = B_0\hat{z}$. Then the equation of continuity and momentum followed by the particles in this system are given by:

\[
\frac{\partial n_j}{\partial t} + \nabla \cdot (n_j \vec{v}_j) = 0 \tag{5.1}
\]

\[
\frac{\partial v_{jx}}{\partial t} + v_{jz} \frac{\partial v_{jx}}{\partial x} + v_{jz} \frac{\partial v_{jx}}{\partial z} = \frac{q_j E_x}{m_j} + \frac{q_j B_0}{m_j c} v_{jy} - \frac{T_j}{m_j n_j} \frac{\partial n_j}{\partial x} \tag{5.2}
\]

\[
\frac{\partial v_{jy}}{\partial t} + v_{jz} \frac{\partial v_{jy}}{\partial x} + v_{jz} \frac{\partial v_{jy}}{\partial z} = -\frac{q_j B_0}{m_j c} v_{jx} \tag{5.3}
\]

\[
\frac{\partial v_{jz}}{\partial t} + v_{jz} \frac{\partial v_{jz}}{\partial x} + v_{jz} \frac{\partial v_{jz}}{\partial z} = \frac{q_j E_z}{m_j} - \frac{T_j}{m_j n_j} \frac{\partial n_j}{\partial z} \tag{5.4}
\]

where, $j = e, i, d$.

We are interested in the three-wave interaction in which the pump wave with frequency $\omega_0$ and wave number $\vec{k}_0$ decays into an ion-cyclotron mode $(\omega_h, \vec{k}_h)$ and a dust-acoustic $(\omega_d, \vec{k}_d)$ mode. Frequency and wave numbers should satisfy the selection rule:
\[ \omega_0 = \omega_l + \omega_h \quad (5.5) \]

\[ \vec{k}_0 = \vec{k}_l + \vec{k}_h \quad (5.6) \]

This resonance condition can be shifted in a plasma where \( T_e \sim \text{keV} \) or when \( T_i > T_e \) and \( T_i \sim \text{keV} \). The excitation of ion-cyclotron wave is important in plasmas with \( T_i(\geq)T_e \) which often occur in space plasmas, theta pinches, some mirror devices at fusion conditions [Saito et al. 1994].

We consider the propagation of lower-hybrid wave (pump),

\[ E_0 = E_0^0 \exp[-i(\omega_0 t - k_{0x} x - k_{0z} z)] \]

The magnetic field is along z-direction. There will be decay waves in the plasma along with the pump wave. Taking Fourier transform of equations (5.1) - (5.4) we get,

\[ -i\omega_0 n_{e1} + i\vec{k}_0 \cdot (n_{e0} \vec{v}_{e1} + n_{e1} \vec{v}_{e0}) = 0 \quad (5.7) \]

\[ -i\omega_0 v_{ex1} = -\frac{e E_{x1}}{m_e} - \Omega_e v_{ey1} - \frac{iT_e}{m_e n_{e0}} k_{0z} n_{e1} \quad (5.8) \]

\[ -i\omega_0 v_{ey1} = -\Omega_e v_{ex1} \quad (5.9) \]

\[ -i\omega_0 v_{ex1} + i v_{ex0} k_{0z} v_{ex1} = -\frac{e E_{x1}}{m_e} - \frac{iT_e}{m_e n_{e0}} k_{0z} n_{e1} \quad (5.10) \]
where \( n_{e0}, n_{e1}, \vec{v}_{e0}, \vec{v}_{e1} \) are equilibrium electron densities, perturbed electron density, equilibrium and perturbed velocities respectively.

We split the electron terms into high frequency part and low frequency part:

\[
 n_{e1} = n_{e1} + n_{eh} \tag{5.11}
\]

\[
 v_{e1} = v_{e1} + v_{eh} \tag{5.12}
\]

\[
 E_1 = E_1 + E_h \tag{5.13}
\]

Substitution of (5.11)-(5.13) into (5.7)-(5.10) leads to the following set of equations:

\[
 \left[ \omega_0^2 + \omega_{ek}^2 - \frac{k_{0x} \Omega_x^2 T_e}{m_e \omega_e^2 (1 + \Omega_e^2 / \omega_0^2)} \right] Y + \frac{\Omega_e^2 e n_{e0} E_{eh}}{m_e \omega_0^2 (1 + \Omega_e^2 / \omega_0^2)} + \frac{e}{m_e} X Z = 0 \tag{5.14}
\]

\[
 \left[ \omega_0^2 + \omega_{ek}^2 - \frac{k_{0x} \Omega_x^2 T_e}{m_e \omega_e^2 (1 + \Omega_e^2 / \omega_0^2)} \right] X + \frac{\Omega_e^2 e n_{e0} E_{el}}{m_e \omega_0^2 (1 + \Omega_e^2 / \omega_0^2)} + \frac{e}{m_e} Y Z = 0 \tag{5.15}
\]

where,

\[
 \omega_{ek}^2 = \omega_{pe}^2 + \frac{k_1^2 T_e}{m_e} = \frac{4 \pi n_{e0} e^2}{m_e} + \frac{k_1^2 T_e}{m_e}
\]

\[
 n_{el} = n_{d1} = X
\]

\[
 n_{eh} = n_{t1} = Y
\]

\[
 k_0 \cdot \vec{E}_0 = Z
\]
In deriving equations (5.14) - (5.15) we have used linearized split Poisson equation

\[ \vec{i} \vec{k} \cdot \vec{E}_h = -4\pi e n_{eh} \]

expression for perturbed ion density \( n_{ii} = Y \) is derived from the following equations for high frequency ion-cyclotron wave:

\[ \frac{\partial n_{ii}}{\partial t} + \frac{\partial}{\partial x} (n_i v_x) + \frac{\partial}{\partial z} (n_i v_z) = 0 \quad (5.16) \]

\[ \frac{\partial v_x}{\partial t} = \frac{eE_x}{m_i} + \omega_i v_y \quad (5.17) \]

\[ \frac{\partial v_y}{\partial t} = -\Omega_i v_x \quad (5.18) \]

\[ \frac{\partial v_z}{\partial t} = \frac{eE_z}{m_i} \quad (5.19) \]

as

\[ n_{ii} = Y = \frac{i_e n_{i0}}{m_i \omega_h} \left( \vec{k}_h \cdot \vec{E}_h + k_{hz} E_{zh} \Omega_i^2 / \omega_h^2 \right) \quad (5.20) \]

Similarly, the equation for low frequency dust-acoustic wave

\[ \frac{\partial n_d}{\partial t} + \frac{\partial}{\partial x} (n_d v_{dx}) + \frac{\partial}{\partial z} (n_d v_{dz}) = 0 \quad (5.21) \]

\[ \frac{\partial v_{dx}}{\partial t} = -\frac{Z_d e}{m_d} E_z - v_{dy} \Omega_d - \frac{T_d}{m_d n_d} \frac{\partial n_d}{\partial x} \quad (5.22) \]
\[
\frac{\partial v_{dy}}{\partial t} = \Omega_d v_{dz} \tag{5.23}
\]
\[
\frac{\partial v_{dz}}{\partial t} = -\frac{Z_d e}{m_d} E_z - \frac{T_d}{m_d n_d} \cdot \frac{\partial n_d}{\partial z} \tag{5.24}
\]

give the expression for perturbed dust density as

\[
n_{di} = X = -\frac{i \ e \ z_d \ n_{d0}}{m_d W_i} \left[ \frac{k_{iz} E xl}{1 - k_{ez} \omega_l^2 \omega_i} + \frac{k_{iz} E xl}{\omega_i} \right] \tag{5.25}
\]

where,

\[
W_i = \omega_i \left[ 1 + \frac{i \ v_{d0}}{\omega_i} - \frac{k_{ix}^2}{k_{pe}^2} \left( \frac{k_{ex}^2 \omega_i^3}{\omega_i^2 - \Omega_d^2} + k_{iz}^2 \right) \right]
\]

\[z_d\] is the number of charges in the dust grain. In dusty plasma, a typical ordering for low frequency regime is \(\Omega_i >> \omega_{pd} >> \Omega_d\) and \(kv_T, \Omega_i, \Omega_d << \omega_0 << \Omega_e\). Under these approximations, using equations (5.18) and (5.23) in (5.14) and (5.15), we get following dispersion relation:

\[
\epsilon = 1 - \frac{\omega_i^2 - \omega_{pe}^2 - k_{pe}^2 v_{Te}^2}{k_0^2 v_{Te}^2} + \frac{i \ A_3}{k_0^2 v_{Te}^2 (A_1 + i A_2 W_i) W_i}
\]

where,

\[
A_1 = \frac{n_{i0} n_{d0} z_d e^2}{m_i m_d} \frac{k_{iz}^2}{\omega_i^2} \left( \frac{k_{iz}^2 + \beta_{iz}^2}{k_{iz}^2} \right) \frac{k_{iz}^2 + \beta_{iz}^2}{\omega_i}
\]

\[
A_2 = \frac{e^2 n_{i0} k_{ex}}{m_e m_i} \frac{k_{ex}^2}{\omega_i} \left( 1 - \frac{k_h \nu_i}{\omega_h} \right)
\]

\[
A_3 = \frac{e^4 z_d n_{d0} n_{i0}}{m_e^2 m_d m_i} \frac{\nu_i}{\omega_h - \nu_i} \left( \frac{k_{ex}^2}{\omega_i} + k_{ex}^2 \right) (k_h^2 + \frac{k_{ex}^2}{k_{hx}^2})
\]

Finally, the growth rate is found to be equal to
\[ \gamma = \frac{\delta_2 \mathcal{E}_0 \pi^2 k_0 \omega_h}{2 \omega_r} \frac{W_i'^2}{W_i'^2 + \nu_{do}^2} \left( \frac{k_{lz}^2}{\omega_l} \right) \left[ 1 + \frac{2 \delta_1 k_{lx} \nu_{do} \omega_l^2}{(k_h^2 + k_{hx}^2/k_{hz}^2) \varepsilon_o} \right] \]

where,

\[ W_i' = 1 - \frac{\varepsilon_i^2}{\omega_i'^2} (k_{lz}^2 \omega_l + k_{lx}^2) \]

\[ \omega_0 = w_r + i \gamma, \delta_0 = \frac{n_{eo} e}{m_i m_e}, \delta_1 = \frac{\varepsilon_i^2 n_{eo}^2}{m_i m_e}, \delta_2 = \frac{\varepsilon_i^4 e^4 n_{eo}^2 n_{do} n_{d0}}{m_i^2 m_d m_i} \]

### 5.2.3 Results and Discussions:

Parametric instability of LHD-wave in dusty plasma may be important for various space and laboratory plasma, viz. ionosphere of the earth, Saturn's E and F-ring, inter-stellar cloud, inter-planetary plasma etc. Here, we have considered earth's lower ionosphere, where plasma consists of ions, electrons and negatively charged dust grains with following parameters:

\[ n_{so} \sim n_{eo} = 15.37 \times 10^4 \text{ / cm}^3 \]

\[ n_{do} = 10^{-4} n_i \]

\[ E_0 = 0.3 \text{ V/m}, \quad B_0 = 0.495 \text{ G} \]

\[ T_e = 0.0724 \text{ eV}, \quad T_i = 0.07 \text{ eV} \]

\[ \nu_{do} = 12 \text{ cm/sec}. \]

Under such a condition, pump wave frequency is found to be \( \omega_0 = 2.0756 \times 10^5, k_0 \lambda_{De}^2 \approx 0.1 \). Frequency matching condition leads to a pump wave vector \( = 0.62 / \text{cm} \). Ion-cyclotron and dust-acoustic waves can be easily excited when a pump LHD wave with suitable frequency and wave number is launched into the dusty-plasma. Growth-rate is found to be of the order of \( 2.33 \times 10^{-20} \) in the ionospheric environment. It is observed that the presence of dust grains has a destabilizing effect. An increase in the dust grains results in the increase in growth-rate of the decay process.

Growth rate is plotted against the parameters \( \omega_0 \), the pump frequency as well as ion-cyclotron frequency \( \omega_h \). It is seen from the figures that growth-
rate decreases exponentially with an increase in the frequency $\omega_0$. On the other hand, growth-rate is proportional to $k_0$, i.e. the electric field of the pump. Growth-rate has higher values of the ion-cyclotron frequency. Parametric decay instability is considered as a major cause in anomalous heating of plasma such as lower-hybrid resonance heating. Because of the fact that electron ion collision frequency rapidly decreases with the electron temperature, ohmic heating cannot raise the plasma temperature in fusion devices to the desired temperature of KeV range. Hence non-ohmic process like parametric instability may be used for the purpose. Moreover, this process of parametric decay of LHD waves in dusty plasma to ion- cyclotron and dust-acoustic waves can explain the heating of the ionosphere and inter-planetary plasma also.

Thus, in this problem we have investigated the parametric decay process in a dusty plasma. It is seen that the pump wave can decay into two daughter waves with frequencies that are of the order of ion-cyclotron and dust acoustic waves, with a growth rate of the order of $10^{-20}$/Sec. The process may play a major role in heating of the ionospheric plasma.

5.2.4 Conclusion:

Parametric decay instability of LHD wave is discussed in dusty plasma that propagates in the $x$-$z$ plane with magnetic field in the $z$-direction. The growth rate is numerically calculated in ionospheric plasma. The wave is found to decay into ion-cyclotron and dust- acoustic waves when pump frequency $\sim 2\omega_0$. Under suitable conditions, this three wave resonance interaction is possible. The process is thought to be one of the causes of ionospheric heating.
growth-rate against ion-cyclotron frequency
Growth-rate vs pump-wave no.

- $7.31 \times 10^{-28}$
- $1.23 \times 10^{-27}$
- $2.23 \times 10^{-27}$
- $2.73 \times 10^{-27}$
- $3.23 \times 10^{-27}$
Growth-rate vs. pump-wave frequency (lower-hybrid)