# Studies on Microwave Response of High Temperature Superconductors Josephson junction and Arrays

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Application of Josephson effect has been attributed in various fields such as magnetometer, gradiometer, bio-medical instruments, digital computer systems, submilimeter sources, detectors and mixers. Application of Josephson junctions (JJ) as submillimeter sources, detectors or mixer are based on the interaction of large number of JJ in complex arrays. The JJ is a natural high frequency source tunable up to terahertz. However the line width of the single JJ is large and maximum power is small. The line width can be narrowed and power increased by using phased locked arrays of many nearly identical JJ. In planar arrays if we increase the number of junctions, the lateral dimension soon exceed the wave length which restrict the tunability of device. This restriction can be avoided if vertical packing of the junction is done.

However, the vertically stacked Josephson junction differs qualitatively from planar structure. The superconducting electrode thickness is much smaller than the London penetration depth, thus screening current in magnetic field or transport current flowing along the superconducting layer spread over $l_L$ couples many stacked junctions. The transport current flowing perpendicular to layer also coupled the adjacent junction via weakening the order parameter within the coherence length x if x is greater than or comparable to electrode thickness. The third mechanism of coupling is quasi-particle diffusion (which takes part in transport current in the resistive state) over diffusion length, which is order of several microns. The single crystal and c-axis oriented thin films of high Tc superconductors (HTSC) forms natural stacks of Josephson junctions with $CuO_2$ layers acting as superconducting electrodes and the $Bi_2O_2$ or $Tl_2O_3$ or $Y_2O_3$ or (Ba, Ca)O layers acting as insulating barrier (Intrinsic Josephson effect).

Large application potential and having interesting physical properties of intrinsic stacked Josephson junction encouraged me to study the I-V characteristic of intrinsic stacked Josephson junction as a function of magnetic field and power of microwave.

In chapter I we review the basic of the Superconductivity needed to understand the rest of the thesis. The Chapter II describes the physics of Josephson junction (JJ) and arrays. Different types of Josephson junction and criterion for large and small junction are discussed. We describe the basic models for calculating the I-V characteristic of JJ. Review of the effect of magnetic field and microwave irradiation on JJ and the intrinsic stacked Josephson junction are presented in Chapter II.

Chapter III describes the formulation and Simulation of I-V characteristics of single

Josephson junction and intrinsic stacked Josephson junction. We model the single junction by RCLSJ in which resistance, capacitance and inductance are taken into account. It is more general. The I-V characteristic of SIS and SNS, weak junction can be simulated by suitably choosing the parameters depending on Capacitance and inductance.

The effect of thermal noise is also taken into account. The noise adds up in external bias current. In our formulation, white noise is approximated by a series of rectangular pulses with Gaussian distributed amplitudes and width smaller than every time constant of Josephson junction. Finally the model comes in the form of non-linear $2^{nd}$ order differential equation, which has been solved by fourth order Range-Kutta method.

The effect of magnetic field is introduced in formulation by suitably introducing the $I_c$ modulation in differential equation. In the formulation of intrinsic stacked, the coupling between different junction is neglected. It has been modelled with one dimensional series array of individual junction where each junction is modelled on the basis of RCLSJ.

In chapter IV, the effect microwave irradiation and noise are discussed. The effect of microwave irradiation on I-V characteristics of Josephson junction as function of power and noise level has been studied. We concluded that the main characteristics of the microwave response of high $T_c$ Josephson weak links observed experimentally could be interpreted within the noise affected RCLSJ model. It is shown that noise causes the appearance of broad minima and reduction of the maxima in the power dependence of the step amplitude as a consequence of its influence on the dynamical mode of the junction Good agreement of our results with experimental data of Kautz et al. is achieved.

Chapter V describes the simulation of the effect of magnetic fields on the I-V characteristic of Josephson junction and arrays. The simulation shows the $I_c$ modulate as function of field like Fraunhofer pattern. The experimental results shows a distorted Fraunhofer pattern. This is due to formation of the Abrikosov vortices penetrating the electrodes. These vortices cause local variation in the critical current in c-direction and hence influence the Fraunhofer pattern.

RCLSJ model are more general in nature. More calculation with suitably choosing the parameter of the junction is further needed to explain the experimental results of effect microwave power irradiation in different geometry. The work is in progress and in future we expect more valuable results.

In modelling the intrinsic stacked Josephson junction we neglected the coupling between junctions, which is not in real. So on dimensional array needs modification in future to take account the capacitive and inductive coupling.