

EXCITATION OF AN OSCILLATOR WITH SEVERAL RESONANT TUNNELING DEVICES INTEGRATED IN SERIES USING RF SOURCE

Olga Boric-Lubecke, Runhua Sun, Dee-Son Pan and Tatsuo Itoh

Department of Electrical Engineering, University of California at Los Angeles

405 Hilgard Avenue, Los Angeles, CA 90024, USA

ABSTRACT

An oscillator using several tunneling devices in series has a difficult excitation condition due to the difference in the I-V characteristics of the individual devices and to the DC instability triggered by the noise. Due to the DC instability, a bias voltage tends to be distributed so that all the devices are biased in the positive differential resistance (PDR) region. A fast electrical pulse, optical illumination or RF source may be used to overcome this problem. The RF source is used only to redistribute the total bias voltage applied to the devices, so that they would all be biased in the negative differential resistance (NDR) region, and is applied for the short amount of time. Simulation results for the RF source excitation will be presented, as well as one experimental example.

INTRODUCTION

Series integration of resonant tunneling diodes has been proposed in order to increase the oscillator output power [1]. Due to the difference in the I-V characteristics of the individual devices and to the DC instability triggered by noise, an oscillator using such a device has several distinct features. Such an oscillator requires a minimum amplitude below which oscillation cannot be maintained, it exhibits a low frequency cut-off, and it has a difficult excitation condition. If the DC bias is applied gradually, the DC instability will divide such a bias among the diodes so that they are all biased in the PDR region. An external RF source may be used to switch the devices from the PDR region to the NDR region [2], so that the oscillation will occur if the circuit is properly designed. The RF excitation frequency may be close to the oscillation frequency of the circuit, or much lower. This paper will treat the excitation with the RF source that has a frequency very close to the

oscillation frequency of the circuit. The lower frequency excitation will be presented elsewhere [3].

Excitation with the RF source close to the frequency of oscillation may be useful in a multiplier circuit. To have a stable oscillation in a circuit with several tunneling devices in series, a large amplitude of oscillation is necessary. If a resonant-tunneling diode is biased in the middle of the NDR region, and large signal oscillation occurs, the diode will behave as a highly nonlinear device, and strong higher harmonics will be generated. A device that has a heating problem, such as pulsed IMPATT diode, may be used as a RF excitation source [2].

If the RF source frequency is close to the oscillating frequency of the circuit, RF power comparable to the oscillator output power is necessary for the switch. Similar to the injection-locking technique, there is a certain frequency band for which excitation is possible for a given RF power. The higher the quality factor of the circuit, the smaller the frequency band will be. There is a cut-off value for the amplitude of the injected signal, below which the diodes cannot be switched from the positive resistance region (PDR) to the negative resistance region (NDR), no matter how close the frequency is to the oscillation frequency of the circuit. Turn-off time of the RF source is not critical, because the circuit is only switching from the amplifier mode to the oscillator mode. This type of excitation is easy to implement experimentally.

THEORY

If the DC bias is applied gradually to the circuit, it will be distributed among the diodes so that they are all biased in the PDR region due to the DC instability. For example, if there were two diodes connected in series, one of them would be biased on the first raising branch of the I-V curve (Fig. 1 (a), (b).), while the other would be biased on the second raising branch of the I-V curve. Current through both devices has to be the same at any instant of time.

When the RF signal is applied, resistive currents will change due to the averaging affect. For the low DC bias point, V_1 (the first diode), resistive current will decrease, whereas for the high DC bias point, V_2 (the second diode), resistive current will increase. Capacitive currents have to compensate for this change. For the first diode capacitive current has to be positive, which means that V_1 will start to increase. For the second diode capacitive current

has to be negative and V_2 will start to decrease. There has to be sufficient change in the resistive currents to start this process, and hence there is a cutoff value for the amplitude of the RF signal below which switching cannot happen.

SIMULATION RESULTS

Several oscillators with two tunnel diodes in series have been designed in a microstrip configuration. The large signal impedance of the diode has been calculated using the procedure described in [4], and the oscillator design was made for several different oscillation amplitudes. EEsof's MWSpice program was used for the simulation. The 5th order polynomial was used to model the tunnel diode I-V curve, and the diodes were assumed to be identical. The DC bias was applied sufficiently slow so that both diodes would be biased in the PDR region at first. After a while, the RF signal was applied, and if its amplitude was large enough diodes would switch to the NDR region. After the RF signal was turned-off, if the circuit was designed for a large enough oscillation amplitude, stable oscillation was maintained.

For the RF frequency close to the oscillation frequency of the circuit, very little RF power was necessary for the switch. With the larger RF source power, the switching happens faster. A turn-off time of the RF signal was not critical at all. Fig. 2. shows the voltage on each diode as a function of time, for the RF source frequency of 2 GHz, which is equal to the oscillation frequency of the circuit. For the RF amplitude of 0.15 V (Fig. 2 (a).), the diodes cannot switch to the NDR region. For the RF amplitude of 0.19 V (Fig. 2 (b).), which is the cut-off amplitude, the diodes switch into the NDR region after fifteen oscillation periods, and oscillation is maintained even after RF signal is turned-off. For the RF amplitude of 0.30 V (Fig. 2 (c).), the diodes switch into the NDR region much faster, after only four periods.

EXPERIMENT

The RF excitation of an oscillator with two tunnel diodes in series with the RF frequency close to the oscillation frequency of the circuit has recently been demonstrated. The oscillator was made in the microstrip configuration. The tunnel diodes were fabricated by Metelics Co., with a peak current of about 0.5 mA. The excitation signal and the oscillator output were separated by a circulator. DC bias was applied using bias T network. A DC current was monitored during the experiment, to check if the diodes were biased in the PDR region or in the NDR region.

The circuit oscillation frequency was 1.861 GHz, with an output power of -29 dBm (Fig. 3.). An RF signal in the frequency range from 1.8 GHz to 1.885 GHz was used for excitation, with input power of -25 dBm. There was 3 dB loss in the measurement system, and hence the oscillator output power was about -26 dBm, whereas the RF input power was about -28 dBm, which is about 2dB lower than the output power. Using an injection-locking technique the quality factor of the oscillator was determined to be about 100.

CONCLUSIONS

The RF source excitation of an oscillator with several tunneling devices in series has been presented. Simulation results for the RF frequency close to the oscillation frequency were obtained. RF excitation with the frequency close to the oscillation frequency was demonstrated experimentally for the oscillator with two tunnel diodes in series.

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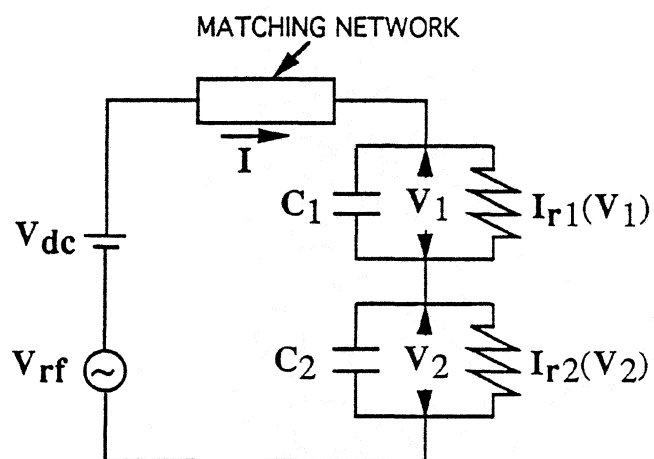


Fig. 1 (a). Equivalent circuit of an oscillator with two tunnel diodes in series

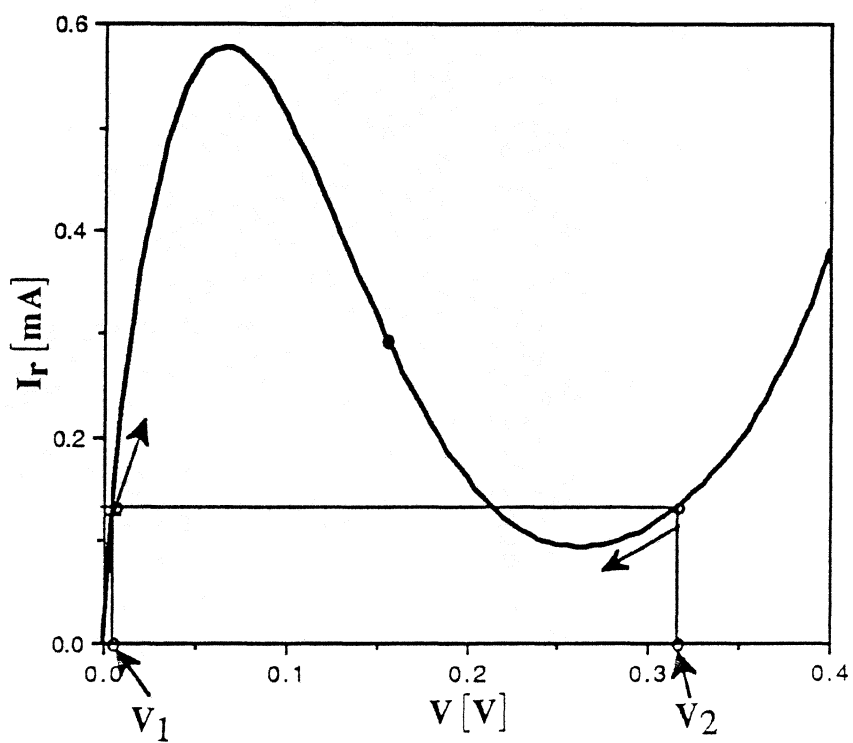


Fig. 1 (b). DC I-V curve of a tunnel diode: initial DC bias voltage distribution

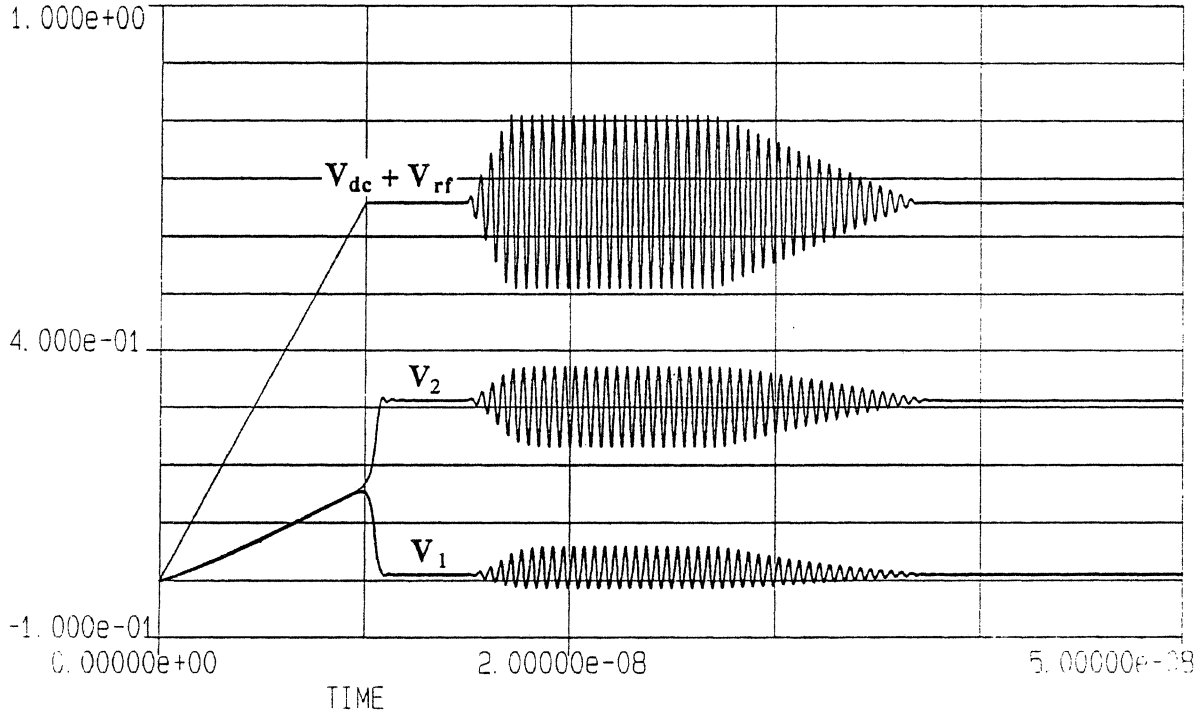


Fig. 2 (a). RF source excitation: $|V_{rf}| = 0.15$ V

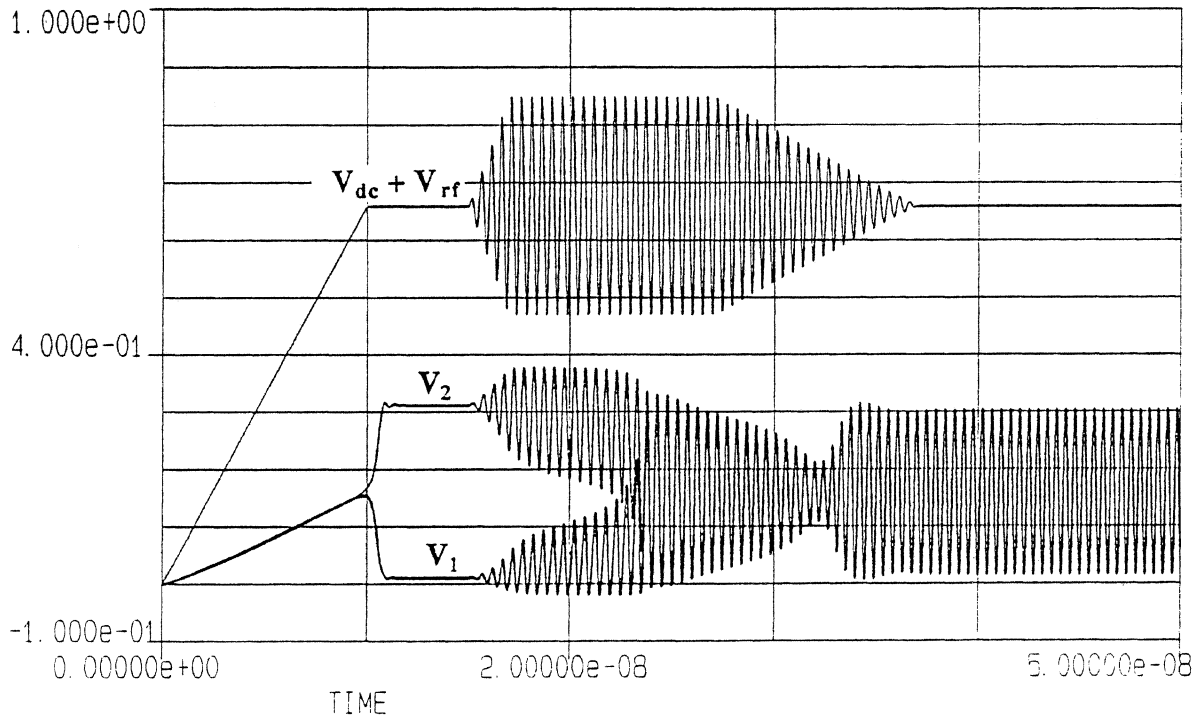


Fig 2 (b). RF source excitation: $|V_{rf}| = 0.19$ V

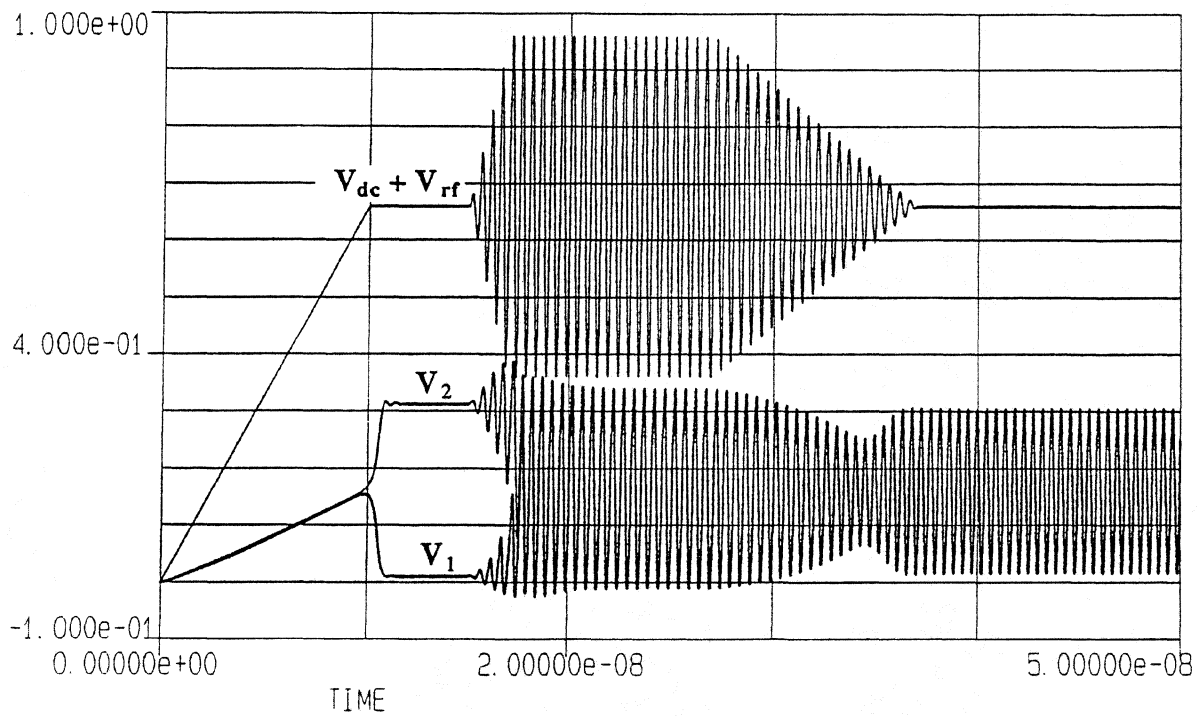


Fig. 2 (c). RF source excitation: $|V_{rf}| = 0.30$ V

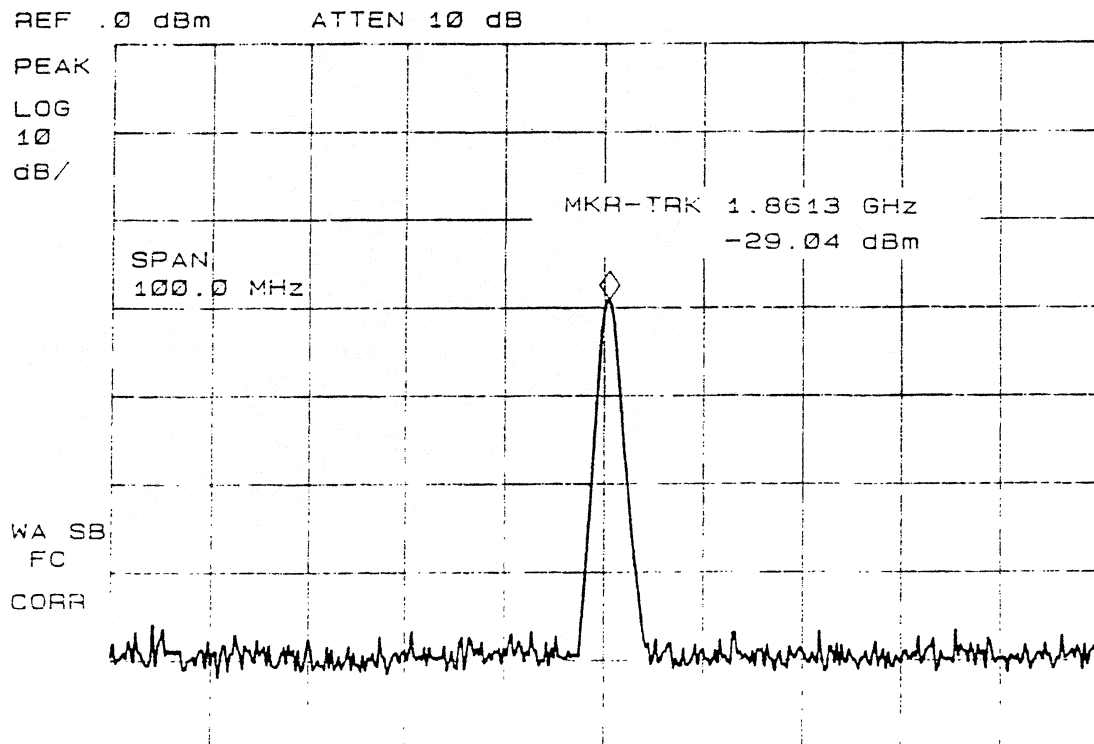


Fig. 3. Oscillation spectrum