SIMPLE LSA CIRCUITS

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Abstract

LSA circuits built entirely from simple coaxial transmission line elements perform well at 4-16 GHz. The lumped-inductive, variable-loaded cavities are fully and precisely characterized. Optimized power, efficiency, frequency variation with bias conditions agree well with relaxation oscillator models, allowing engineered circuits to be designed for any operating regime.

Introduction

An important operating regime for practical GaAs transferred electron oscillators is the LSA relaxation mode.[1] It is characterized by large signal oscillations at bias voltages greater than twice threshold where the frequency is independent of (but usually larger than) the transit-time frequency, being determined by circuit and device parameters and bias voltage. In this mode, high pulsed power and good efficiency can be obtained: efficiencies of over 20% are predicted for X-band, several hundred watts (X-band) have been obtained for duty cycles up to 1%.

Circuit Design

The circuit required for this mode consists of a cavity which behaves as an inductance as the fundamental and second harmonic, a load resistance and a means of applying bias to the diode. In such circuits (Figure 1) an unencapsulated diode can be represented as a non-linear resistance in parallel with the geometrical diode capacitance. Provided that correct bias and loading conditions are met, the system oscillates with a frequency f which varies approximately as $\frac{1}{f} = 2/LC_o + \frac{L}{R_o}\frac{V_t}{V_b}$.[1] There is considerable scope for voltage tuning, $\frac{df}{dV_b}$ is always positive. Power and efficiency increase monotonically with bias provided the simple circuit can be realized.

Figure 2 shows cavities which have been designed and built at RRE to realize accurately the circuit of Figure 1b. They have the following features:

1 They are constructed from simple coaxial transmission line elements. The equivalent circuits of the elements are precisely known, and, since the cavities are built within the precision 7 mm air line system, they can be up to 18 GHz.

2 Designed primarily for X-band operation, the cavities are very broad band, and LSA relaxation oscillations have been seen, using available LSA diodes, at frequencies from 4 to 16 GHz.

3 Heat sinking is readily incorporated in the design, allowing up to 1% duty cycle operation.

4 The circuits can incorporate additional transmission line elements which may be tuned for optimum output power with little effect on frequency.

Simulation and Experimental Results

A Runge-Kutta procedure has been used to simulate the lumped-inductive model of Figure 1b, inserting the diode non-linear resistance in the form

$$i(v) = \frac{V/R_o + I_o(V/V_s)^4}{1 + (V/V_s)^4}$$

Resulting waveforms deliver information which have been compared with experimental results. Frequency, power, efficiency and harmonic constant show good general agreement.

When a capacitance element is introduced into the output line, the predicted load impedance changes with the element's position, while the reactance stays almost constant. Thus output power, which is dependent on load impedance, can be varied to maximum without substantially changing the oscillation frequency.

Conclusions

The complex nature of some LSA cavities[2] contrasts sharply with the simplicity of the basic LSA relaxation oscillator model. The work outlined here demonstrates the validity of the simple model and the ease with which it can be implemented. More sophisticated control of the oscillator, for example the use of second harmonic tuning to increase efficiency[3], can be incorporated without modifying the basic simple circuit.

References

1 Jeppsson B and Jeppesen P, "LSA Relaxation Oscillator Principles", Trans IEEE, ED-18, pp 439-449 (1971).

2 Jeppsson B and Jeppesen P, "LSA Relaxation Oscillations in a waveguide iris circuit", Trans IEEE, ED-18, pp 432-439 (1971).

3 Camp W O Jr, "High-efficiency GaAs transferred electron device operation", Trans IEEE, ED-18, pp 1175-1184 (1971).

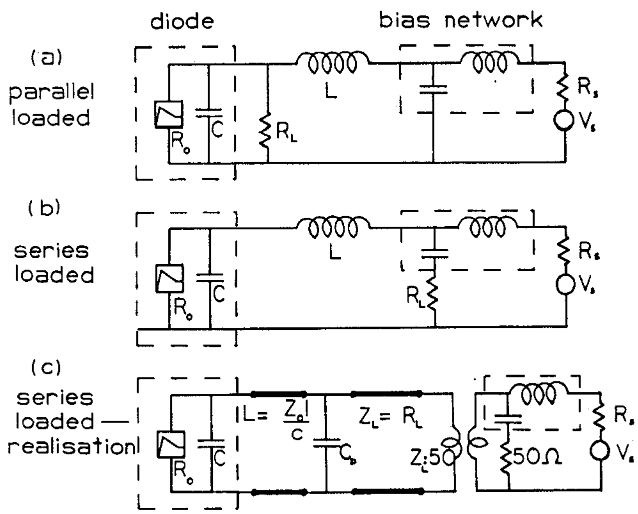

Fig 1 LSA Relaxation Oscillator Circuits

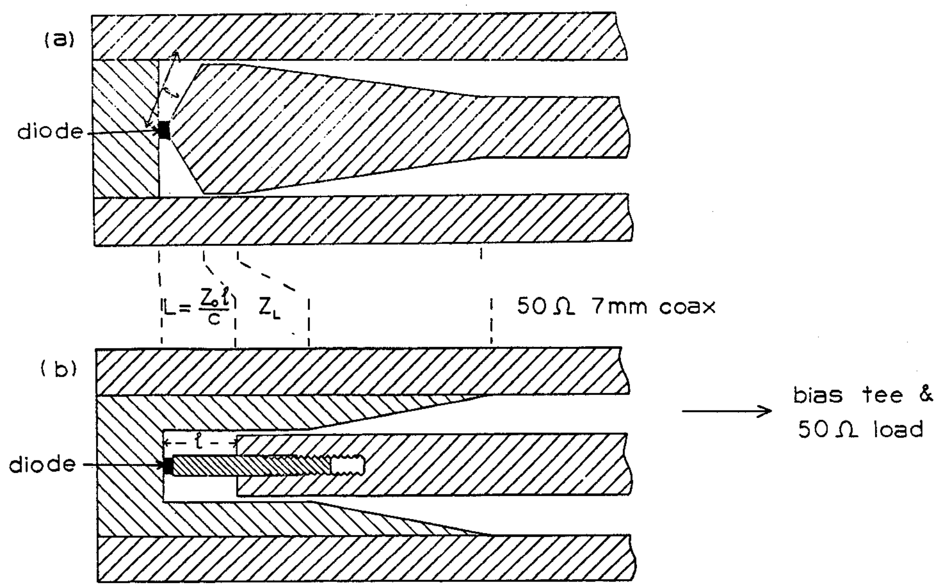

Fig 2 Co-axial LSA Circuits