POWER COMBINING IN EVANESCENT MODE RESONATORS

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Waveguide-below-cutoff techniques have been utilized to combine the power of a multiple-diode oscillator. Two structures are described; a simple T-junction with narrowband performance and a transmission cavity oscillator showing low noise and a large tuning range.

Introduction

Some limitations of great practical importance are commonly associated with power combining circuits: low Q-factor (poor frequency stability and high FM-noise), narrow tuning range, large size, and poor manufacturability. Although a lot of realizations for multiple-diode oscillator circuits have been reported, there seems still to be a need for an approach that meets all these requirements simultaneously. An approximate solution to this problem will be described here.

The multiple-diode oscillator has been realized with evanescent mode resonators. This waveguide-below-cutoff technique has recently been shown to lead to a good electrical performance for various active microwave components[1]. Its significant features are: lumped element character of networks, broad-band performance, lack of parasitic circuit elements of capacitive character, small circuit losses, small size, low weight and cost. Two oscillator structures will be described: The first one is characterized by a very simple construction, it has, however, a low Q-factor. The second one shows an excellent electrical performance at the sacrifice of a higher expenditure.

A Low-Q Power Combiner

The first circuit has been sketched in fig. 1. It consists of a waveguide T-junction (in the H-plane) with a rectangular waveguide below cutoff (1), which is coupled by an aperture (2) in the partition wall to the output waveguide (3) above cutoff. 4 active elements (6) can be mounted in the evanescent mode resonator. Their mutual coupling can be influenced by the lossy rods (5). The circuit is tuned by the screws (4), which act as capacitors.

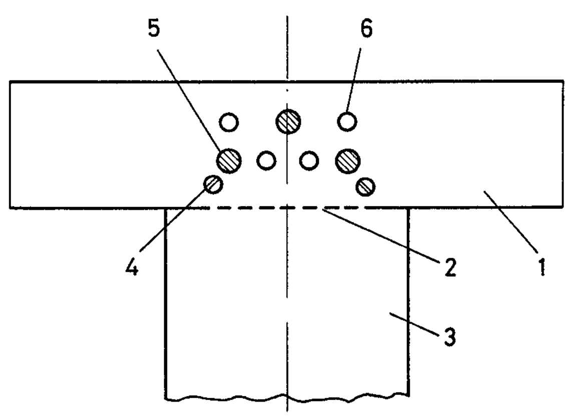

Fig. 1 Sketch of a low-Q multi-device oscillator circuit

The design principle for the multiple-device oscillator is, that the circuit must not oscillate if one diode is inactive. Resonance conditions are only established by the compound effect of the electronic capacitances of the diodes and the capacitances of the screws together with the inductance of the waveguide housing. The 3 damping resistors prevent unwanted modes of oscillation. Their power consumption can be made less than 0.5 dB. The two symmetrically mounted tuning screws may be replaced by one screw on the symmetry line. Two screws have, however, been preferred, because they offer a means for compensating for unsymmetries in the diodes.

The circuit has been designed for 7 and 20 GHz. Its efficiency amounts to almost 100 per cent. The operating frequency can be tuned by the screws over 400 MHz at 7 GHz and over 840 MHz at 20 GHz, respectively. In the case of 4 Gunn elements neither mode jumping effects nor difficulties with turning-on the oscillator can be observed. The oscillations cease, when the bias of one arbitrary diode is switched off. The circuit is equally well suited for Impatt diodes. Its electrical performance is the same as for Gunn elements except for the tuning range, which degrades by a factor 1/3.

The loaded Q-factor of the oscillator is less than 10. In order to improve the frequency stability, one can mount a thin slice of ceramic with negative temperature coefficient of its dielectric substrate in the gap of a tuning screw. This reduces the frequency drift with temperature to about 200 kHz/K. The power-frequency relationship is shown in fig. 2 for both free-running and synchronized state. The locking bandwidth of the oscillator with 4 Gunn elements amounts to 500 MHz at an input signal level of -13 dB below the output.

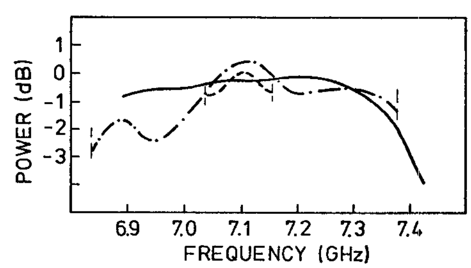

Fig. 2 Output power versus frequency for the oscillator structure of fig. 1
——— free-running; — . — . — synchronized with 13 dB gain;
— — — — — synchronized with 20 dB gain

A widely tunable, high-Q circuit

The second oscillator circuit is shown in fig. 3. It is the transmission cavity stabilized structure, which has already been introduced in [1]. It contains, however, several active devices (4) now, which are mounted in evanescent mode resonators (3). The TE_{011}-mode circular waveguide cavity (2) is coupled by slots in its cylindrical wall to the evanescent mode resonators on one hand and to the outgoing waveguide above cutoff (1) on the other. The cavity, which acts as the power combining network, can be tuned by the plunger (6). Each evanescent mode resonator contains a damping resistor (5), which has been made from lossy material (pertinax).

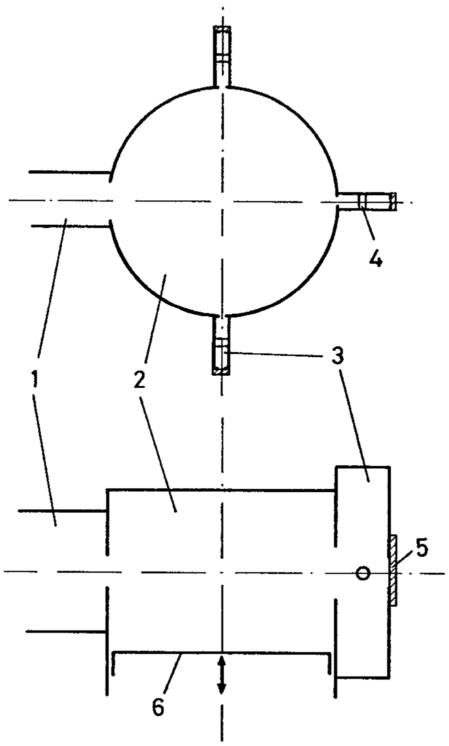

Fig. 3 Power combining in a high-Q transmission cavity

The compound oscillator structure resembles the single-cavity multiple-device oscillator of Kurokawa[2] in that a waveguide cavity has been used as the power combining element. From this and the symmetrically arranged mounts of the active devices one can conclude that Kurokawa's stability analysis holds for our circuit, too, provided that the oscillation frequency equals the natural frequency of the cavity and that other cavity modes cannot be excited. The only difference between the two oscillators is, that the loaded Q-factor of our realization is about an order of magnitude higher. Hence the oscillator structure of fig. 3 shows excellent long-term and short-term frequency stability.

It has to be expected that a crucial point in the performance of the high-Q oscillator is a narrow (mechanical or electronical) tuning range. This can be overcome, however, if the following design principle is obeyed: The diode mounting structure must be directly coupled to the cavity without any intermediate transmission line, which would only introduce further resonances and thereby jumping effects. The diode must, moreover, be nonresonant in order to enlargen the frequency tuning range. This can be fulfilled by an evanescent mode resonator, which contains no capacitive tuning screws.

These ideas have led to the oscillator arrangement shown in fig. 3. The damping resistors are necessary in order to eliminate mode-jumping effects of the multiple-device structure. They must, however, even be used for a single-diode oscillator in order to achieve a single-valued tuning range. This result can be drawn from [3], where it has been proven that stable oscillators can only build up, if the diode mounting network between diode and cavity is lossy. For an illustration we will regard the equivalent circuit of fig. 4. Z_D means the diode impedance and Z_c the cavity impedance including the load. The coupling network will be represented by its equivalent T-section with series impedance Z_s and parallel impedance Z_p.

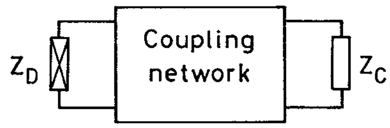

Fig. 4 Equivalent circuit for a single-diode cavity stabilized oscillator

Due to [4] stable oscillations are sustained, if the frequency slope of the imaginary part of the diode input impedance is positive. It has been shown in [3] that this condition is fulfilled, if Z_p has a nonzero real part. Hence the damping resistor, which has been introduced in the diode mount, fulfills two operations: it eliminates mode-jumping effects of the multiple-device array and simultaneously guarantees a single-valued tuning curve.

The losses can alternatively to the solution of fig. 3 also be introduced in the bias filter, what is attractive for Impatt diodes. Matching the diodes and tuning the output power is performed by the size of the coupling slots. Thus the power loss in the cavity can be chosen depending on the required loaded Q-factor. This power loss might be less than 0.5 dB.

One problem remains still to be discussed: the effect of higher-order cavity modes on the oscillator performance. For illustration, the load line of a transmission cavity single-device oscillator has been plotted in fig. 5. To this end the oscillator assembly must be tuned for maximum power output with a prescribed power loss in the cavity. This power loss is determined by the wanted loaded Q-factor of the oscillator. The active device is then removed and replaced by a coaxial probe which is inserted opposite to the bias filter. The load line can then be measured by means of a network analyzer.

The resonance loops are due to the TE_{011}- and TE_{311}-mode. They do not only limit the single-valued portion of the tuning range but can furthermore introduce instabilities in a multiple-device oscillator. They can only be avoided if the cavity dimensions are chosen such that the unwanted modes are widely separated from the wanted mode. This, of course, limits the mechanical tuning range. (In measuring the load line, a reference plane has been chosen, which did not correspond to the diode port. Hence the measured result is only correct besides a possible phase shift.)

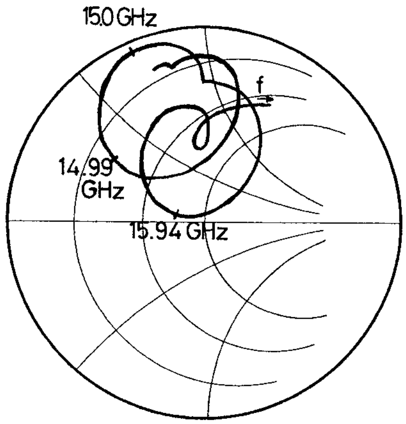

Fig. 5 Load line for a cavity stabilized Gunn oscillator

An oscillator has been built at 15 GHz containing 3 Gunn elements or 3 Impatt diodes. The single-valued tuning range was in excess of 800 MHz with an output power variation of 1 dB. A loaded Q-factor of larger than 1000 has been achieved at the expense of only 0.5 dB of output power. The tuning curve is shown in fig. 6.

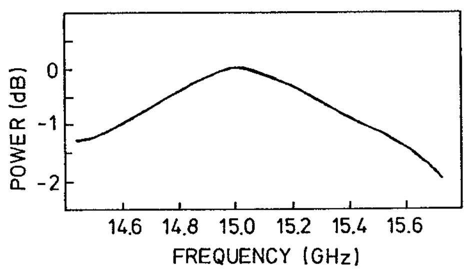

Fig. 6 Output power versus oscillation frequency of a cavity stabilized oscillator with 3 Gunn elements

Conclusions

Two power combining structures have been described which do not show any mode jumping. Their circuit efficiency is almost 100 per cent. The structures can be realized also in the millimeterwave region. Space requirements will set an upper limit of about 50 GHz to the second circuit and of about 30 GHz to the first one.

References

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