HIGH-POWER, LOW-NOISE AVALANCHE DIODE OSCILLATORS

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Introduction - An approach to higher-power generation with avalanche diodes is described which uses (1) passivated devices in order to avoid the use of conventional packages, (2) multiple-diode chips for reducing the thermal resistance, and (3) cascading waveguide oscillator mounts for efficient power combining.

Device Design - The devices used in the present oscillator experiments are passivated mesa silicon $P^+N\ N^+$ junction diodes. Uniform avalanche breakdown, which is a prerequisite for this application is achieved by double diffusion of the N^+ region where the avalanche is forced to take place in a well defined area in the bulk of the diode. Surface passivation of the diode with a thin insulating layer of silicon oxide permits the device operation in open ambient and thereby dispensing with the necessity of packaging. This allows greater flexibility in incorporating the device in the microwave circuit. Diode chip is fabricated such that the total active area of the device is divided into several small areas, physically separated from each other sufficiently so that they are thermally isolated. This approach of multiple diodes reduced thermal resistance and increases the power dissipation capability of the diode. A typical arrangement used six diodes on a 30 x 30 mil chip.

Oscillator Mount - Figure 1 illustrates the design which keeps the device under spring pressure (spring incorporated in the DC bias cylinder, not shown in Fig. 1) in the gap of the primary, conical radial resonator. The oscillator cavity was formed by inserting this mount between a movable waveguide short and a slide-screw tuner or other tuning element. Waveguide sizes WR90 and WR62 were used for X and Ku band operation, respectively. Power combining was accomplished by cascading two or three mounts with or without waveguide spacers[1,2].

Single-Mount Oscillator Performance - Tests were conducted mainly at frequencies around 11 and 13 GHz, with devices having breakdown voltages 85V and 65V, respectively. Some data were also taken near 16 GHz (V_{br}=55V). The highest power obtained were 1370 mW at 10.52 GHz, 1180 mW at 12.65 GHz and 875 mW at 15.95 GHz. The corresponding highest efficiencies were 7.8%,6.8%, and 5.2%, respectively. The most detailed tests were carried out with X-band units. Typical tuning bandwidths (between 1 dB points) of single-mount oscillators were ∿ 1.5 GHz. Noise measurement data are given in Fig. 2. These come very close to specifications for low-noise oscillators used as up-converter pumps in heterodyne FM communication transmitters.

Power Combining - The data presented in Fig. 3 and 4 were obtained using asymmetrical mount design which permits varying the device spacing simply by cascading the proper combination of three different mount sizes. In order to further simplify the experimental procedure up to three mounts of each size were built and pretested as oscillator units. Their maximum power outputs ranged from 1.0 to 1.14 W and their frequencies of maximum power output differed by less than 3%. Curves are not drawn through the data points of Figs. 3 and 4 because, in general, the adjacent data points were not taken with the same devices. However, the described experimental procedure gives most useful results because assembling of composite oscillators in production would proceed essentially in the same way.

Figures 3 and 4 show that power combining in the two mount X-band oscillator was highly efficient and varied very little over a wide range of device spacings. Power combining in the three-mount X-band oscillator was more sensitive to device spacing and tuning but nevertheless highly efficient. The best result was obtained with device spacings of 3.0 cm. The power output was 3.2 W at 10.6 GHz, the power combining efficiency 100% and the DC-to-RF conversion efficiency 6.5%. A 1 dB tuning bandwidth of 191 MHz was measured.

Ku-band composite oscillators with two cascaded mounts were also built and optimized for a predetermined frequency range. The resulting structure with a device spacing of 2.9 cm gave 2.05W at 12.66 GHz with 99% power combining efficiency and 5.6% DC-to-RF conversion efficiency.

Noise measurements were carried out on two-mount composite oscillators only. The FM noise showed the tendency to slightly exceed that of the single-mount oscillator (order of magnitude: 1 dB) but the AM noise was substantially lower in the composite oscillator (order of magnitude: 10 dB). This is in good agreement with the results obtained by Rucker[3] from his composite oscillator which consists of five paralleled coaxial cavity oscillators using avalanche diodes.

Conclusion - The power capability and low-noise property of the described devices and power combining scheme open up attractive possibilities of applications in communication systems such as: (1) up-converter pump for heterodyne transmitter, (2) frequency-modulated transmitter oscillator, (3) injection-locked oscillator as power amplifier.

References

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3. Rucker, C.T., "A Multipled-Diode High-Average Power Avalanche-Diode Oscillator," IEEE Transactions, MTT-17, pp. 1156-1158; 1969.

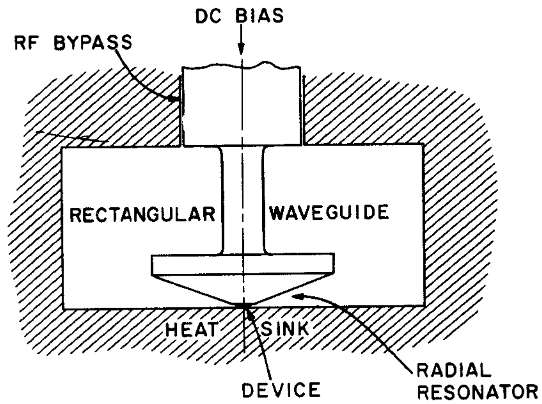

Fig. 1: Sketch of oscillator mount designs for X-band and Ku band.

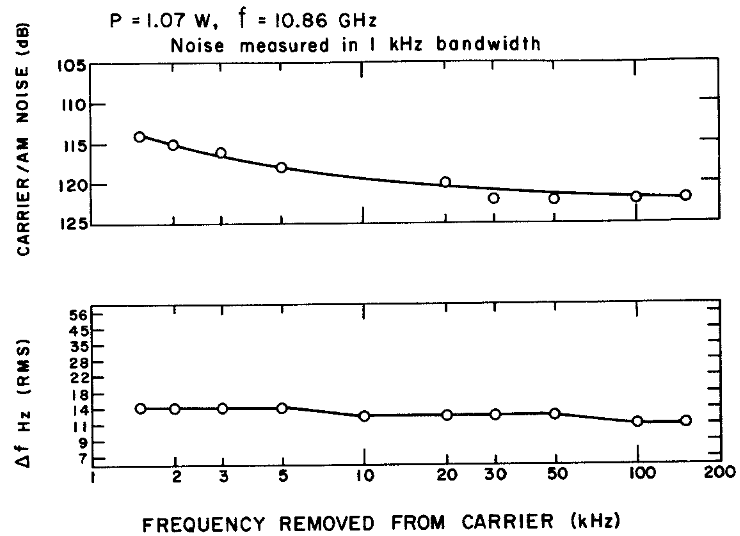

Fig. 2: Typical noise performance of single-mount, X-band oscillator.

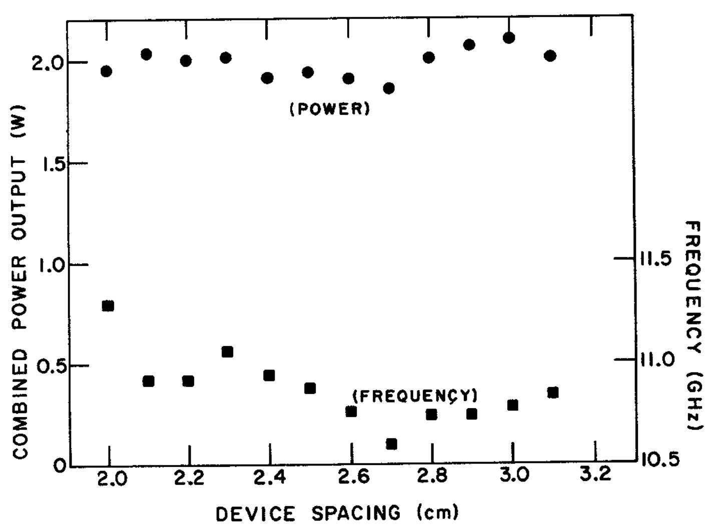

Fig. 3: Combined maximum power outputs and corresponding frequencies for the various two-mount, composite oscillator structures with different device spacings.

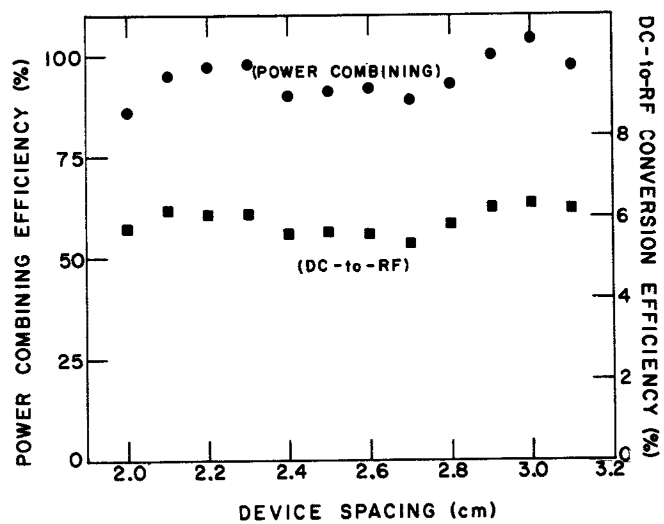

Fig. 4: Power combining efficiency and DC-to-RF conversion efficiency for the power output of Fig. 3.