GUNN DIODE POWER COMBINING AT U-BAND

Y. Ma and C. Sun
Hughes Aircraft Company
3100 West Lomita Boulevard
Torrance, California 90509

Abstract

A modular approach for combining many Gunn devices has been developed. By stacking simple two-diode wafer modules, output power of 620 mW was achieved at around 45 GHz from 6 Gunn devices with a combining efficiency of 86 percent. The locking bandwidth was about 200 MHz with 20 dB locking gain.

Introduction

Combining more than one Gunn diode in a microwave circuit is a very attractive way to obtain clean high-power signal sources. Recently several different schemes have been reported for circuit-level Gunn-diode power combining in the low millimeter-wave frequency range.[1-3] However, the number of combining diodes has been limited to 4. This paper describes a convenient method for combining a large number of Gunn devices in a resonator as was first proposed by Kurokawa.[4] A simple two-diode wafer module is developed and the power combining is accomplished by stacking the wafer modules with minimal circuit adjustment. A maximum power output of 620 mW was achieved at 44.6 GHz from 6 Gunn diodes.

Gunn Diode

The Gunn devices used were made from vapor phase multiple epitaxial n-type gallium arsenide. It consists of a buffer layer of 2.2 μm with approximately 10^{18} carriers/cm^3 and an active layer of 2.7 μm with 10^{16} carriers/cm^3. The ohmic contact on both sides of the diode is a gold-germanium nickel alloy covered by tungsten and gold. The diode is mounted on a copper heatsink and surrounded by a 35 mil diameter ceramic pill package with cross-strap gold ribbon configuration. The threshold current and voltage of the diode are 1.3-1.4 V and 1.8-2.0 A respectively. The diode has a broad operating frequency range from Ka-band to W-band. Typical optimum power output at around 50 GHz is between 100 mW and 120 mW from a single diode. The operating voltage is 4-5 V and the operating current is 1.4-1.6 A.

Two-Diode Wafer Module

Figure 1 shows the assembly photograph of a two-diode wafer module developed for convenient power combining. The two Gunn diodes are mounted at the bottom wall of a full-height waveguide and biased through the round posts insulated by Eccosorb chokes. The diodes could be recessed into the waveguide wall by introducing a spacer of which the thickness and hole size can be controlled for proper impedance matching. The Eccosorb chokes can also be moved up and down for further impedance matching as well as for frequency stabilization. The thickness of the wafer can be adjusted depending on the frequency of interest.

Optimum power output of 240-250 mW was obtained from a two-diode module in the frequency range between 44 and 48 GHz. The DC to RF conversion efficiency was about 2 percent. The mechanical tuning range was about 5 GHz and the injection locking bandwidth was about 120 MHz with 20 dB locking gain.

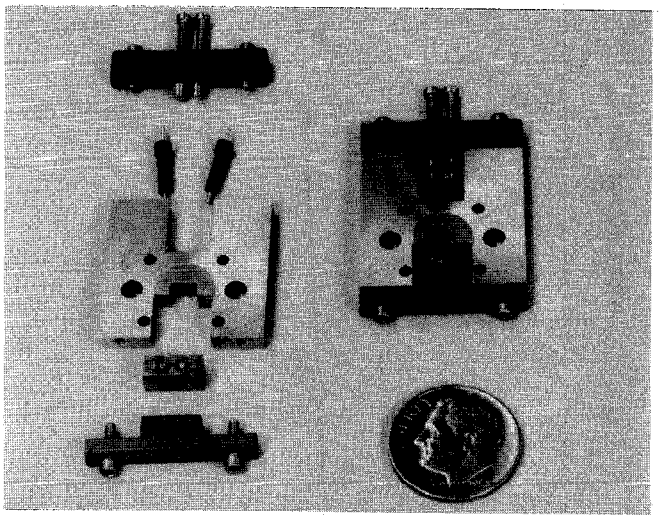

Figure 1 Assembly photograph of two-diode wafer module.

Combiner Characteristics

More diodes were combined by simply stacking the wafer modules. Each wafer module was adjusted individually and as more wafers were stacking together only slight circuit readjustment was required for optimum operation. 620 mW output power was obtained from the six-diode combiner with 1.63 percent DC to RF conversion efficiency. The combining efficiency was about 86 percent for this combiner.

Mechanical tuning was conducted by moving the sliding short position and the characteristics is plotted in Figure 2 with the corresponding output power at each frequency. The single-diode data were measured in a reduced-height waveguide cavity instead of full-height waveguide resonator. In general, the tuning range decreases with the number of combining diodes. The tuning range is limited by the frequency jump at the lower end and by the frequency saturation at the higher end.

Injection locking characteristics of the combiners are shown in Figure 3. The locking gain-bandwidth characteristics generally follow very closely to the theoretical values. Obviously the reduced-height waveguide single-diode cavity has lower circuit Q than the full-height waveguide combiner resonators. Note that the circuit Q decreases as the number of diodes increases in the combiner circuit. The locking bandwidth was about 200 MHz with 20 dB locking gain and about 50 MHz with 30 dB locking gain respectively.

Both the oscillation frequency and output power of the six-diode combiner decreases with temperature. The change of oscillation frequency is about 30 MHz over the temperature range from 0°C to 60°C.

Figure 4 shows the photograph of the six-diode combiner resonator. It consists of 3 two-diode wafer

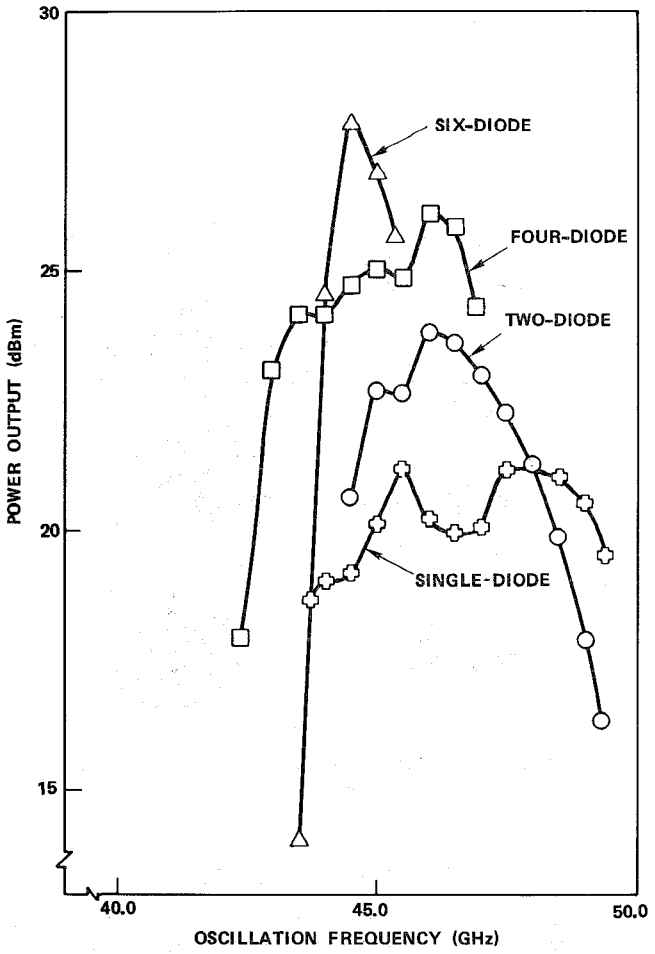

Figure 2 Mechanical tuning characteristics of the combiners.

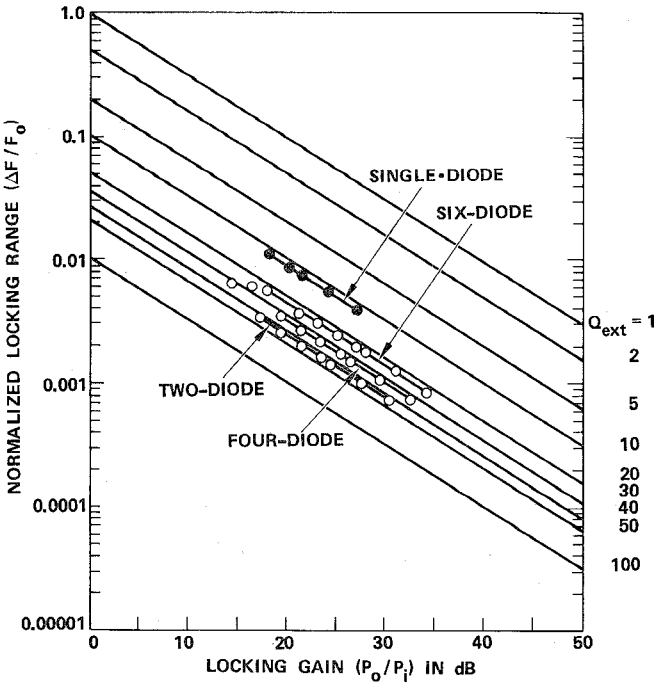

Figure 3 Injection locking characteristics of the combiners.

modules, a tuning short block, and an output block with a screw tuner.

Conclusions

More than 600 mW output power was achieved at around 45 GHz by combining 6 Gunn devices in a waveguide resonator. A compact two-diode wafer module has been developed and the power combining is accomplished by simply stacking the wafer modules. We believe that more diodes can readily be combined using this technique for even higher output power with proper heat transfer mechanism. The combiner should provide sufficient power output for low-noise parametric amplifier, medium power transmitter, and frequency multiplier applications. The same combining approach can also be extended for higher millimeter frequencies.

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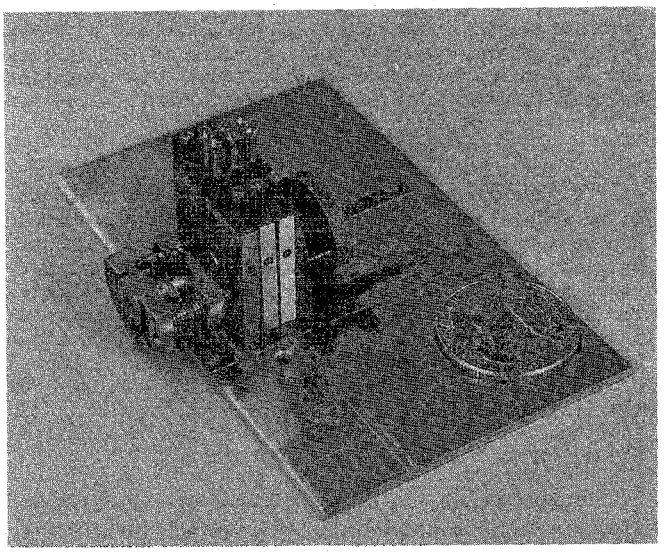

Figure 4 Hardware of six-diode combiner.