A ONE WATT CW AVALANCHE DIODE SOURCE OR POWER AMPLIFIER

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Methods of extending the dynamic range of solid state negative resistance amplifiers have been suggested which employ a "travelling wave" approach,[1,2] and a cascading approach.[3,4] This has also been applied to oscillators.[5] There are reports of frequency locking of several coupled oscillators to combine their individual output powers.[6,7] This paper describes the generation of 1 Watt CW at X-band by a specific method of cascading one avalanche diode oscillator and three avalanche diode power amplifiers. The diodes used are the diffused gallium arsenide units,[8] recently constructed in an inverted structure in the Micro State device laboratory, capable of generating over 300 mW CW at X-band.

An elementary analysis of the direct-coupled amplifier circuit shown in Figure 1 may be developed. The circuit is intended to be used as a building block in a chain of such amplifiers where the negative R is coupled successively more weakly to the line with the coupling criterion being the extraction of maximum power from the device. One transformer adjusts the coupling to the diode, while the other matches the input.

Assuming that the oscillator delivers its maximum output power, and that each succeeding amplifier stage delivers the same, the gain of the N'th stage G_N, will be $\frac{N + 1}{N}$. The gain is related to the normalized transformed negative resistance by

$$G = \frac{\tilde{R}'}{1 + \tilde{R}'} \tag{1}$$

Thus

$$\tilde{R}'_N = \frac{G_N}{1 - G_N} = -(N + 1) \tag{2}$$

The normalized transformer impedances can be shown to be

$$\tilde{Z}_{T1N} = \sqrt{\frac{N + 1}{N}}$$

$$\tilde{Z}_{T2N} = \sqrt{-(N + 1)\ \tilde{R}} \tag{3}$$

It must be remembered, however, that the negative resistance, R, is that which one obtains when the device is operating in a saturating condition.

While this analysis has been carried out for a direct-coupled amplifying mode, it may readily be applied to a circulator-coupled circuit by modifying the gain equation. Although circulators contribute additional loss, they simplify the construction of the amplifier, and are useful when the number of stages is limited. A fourth stage, for example, will have 1 dB gain, from which must be subtracted the circulator loss. For convenience, the actual source which was constructed used circulators.

An aid in the design of this type of network is a display of the actual power added vs. the input level in dBm with the low-level gain as a parameter. A typical set of curves of this type demonstrates that the actual power added drops off sooner with increasing input power level for higher low level gain. There is also the trend toward greater possible efficiency as the low level gain is reduced since the maximum power added moves upward, while the dc bias remains fixed.

A source was constructed as shown in Figure 2. Each of the diodes was capable of supplying 250 to 300 mW when optimized as an oscillator at about 50 mA bias. Breakdown voltages were of the order of 60 volts, junction capacity about 2.5 pf, and efficiencies were 6 to 10%. When the gain of each stage was optimized for maximum efficiency, the output was slightly more than one watt. The gain was about 6 dB. It is expected that substantially better efficiency can be obtained in a direct coupled or hybrid coupled mode of operation where, in view of the low gain, at most one non-reciprocal device would be required to insure stability.

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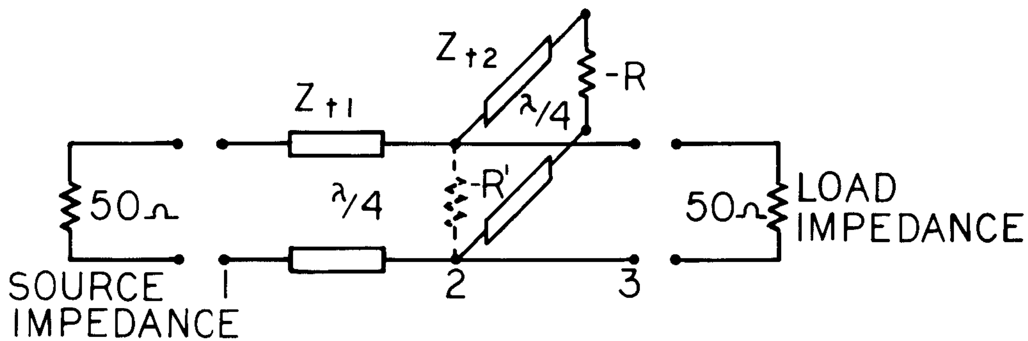

FIGURE 1
DIRECT-COUPLED CIRCUIT

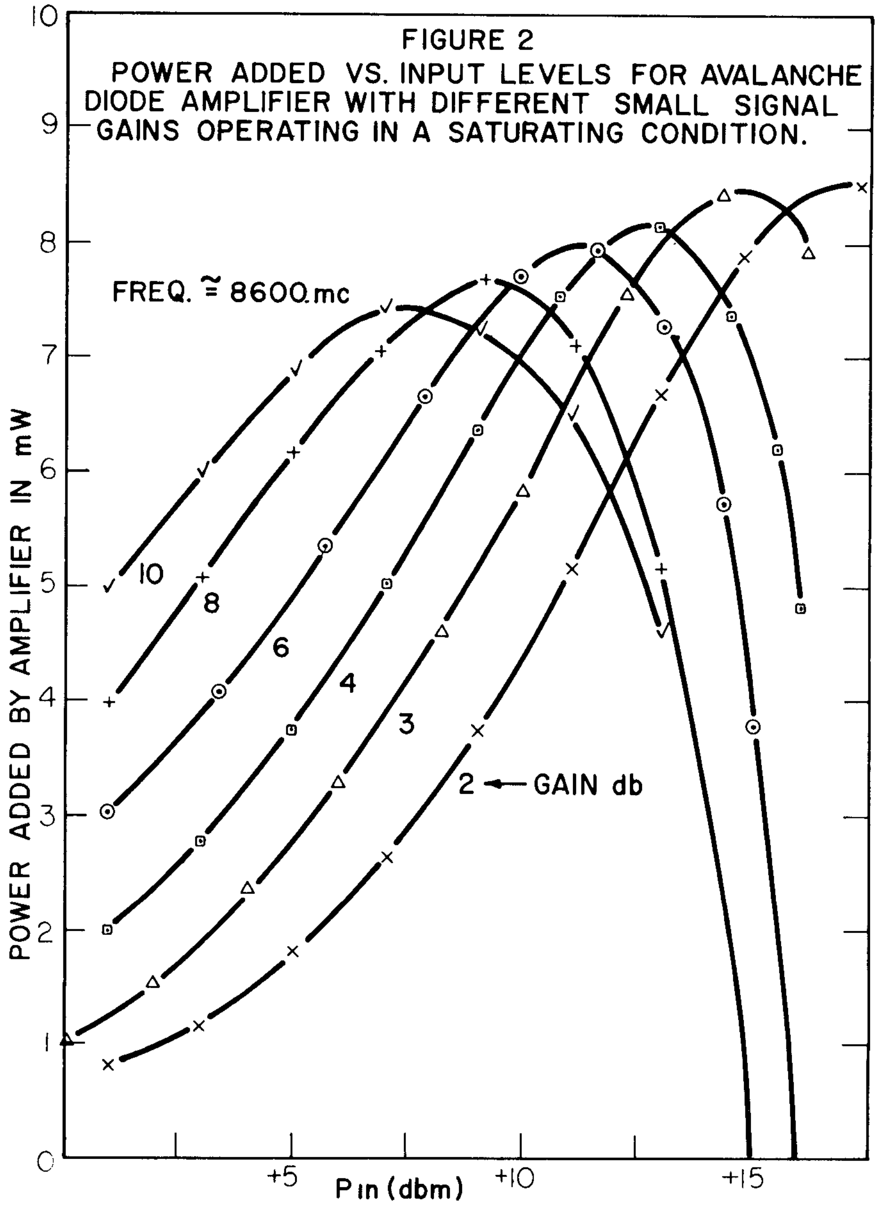
FIGURE 2
POWER ADDED VS. INPUT LEVELS FOR AVALANCHE DIODE AMPLIFIER WITH DIFFERENT SMALL SIGNAL GAINS OPERATING IN A SATURATING CONDITION.
FREQ. ≅ 8600 mc
POWER ADDED BY AMPLIFIER IN mW
Pin (dbm)
+5
+10
+15
0
1
2
3
4
5
6
7
8
9
10
10
8
6
4
3
2 ← GAIN db

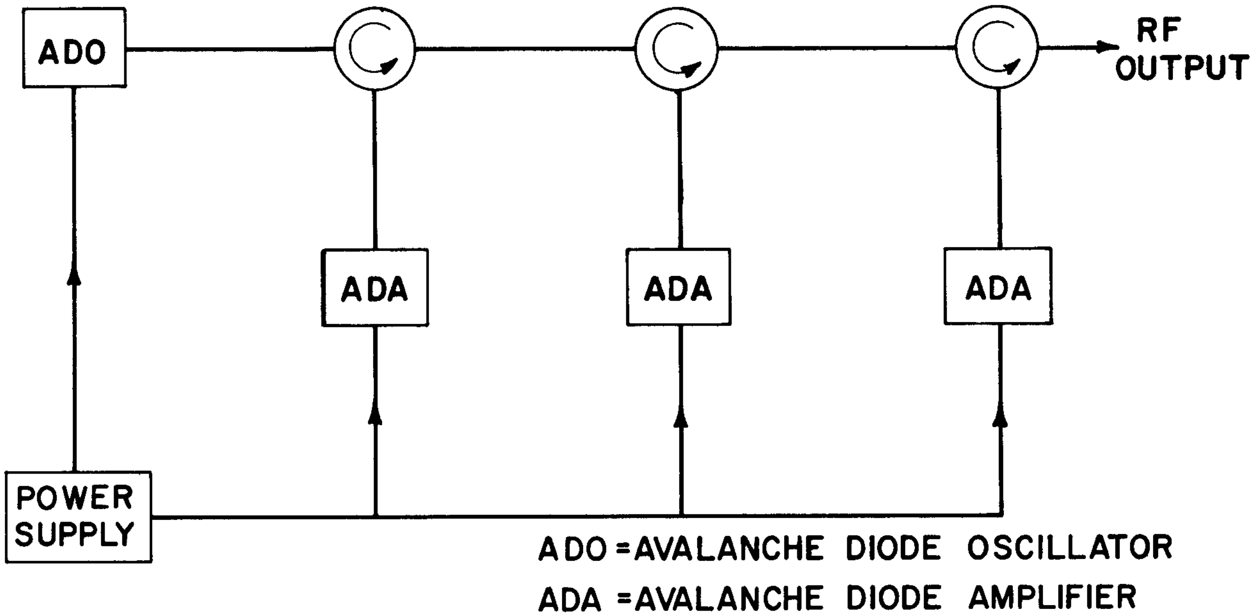

FIGURE 3

CASCADED AVALANCHE DIODE SOURCE