LOW-COST MODULAR 100-WATT PEAK 10% BANDWIDTH MICROSTRIP IMPATT AMPLIFIER

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ABSTRACT

A New IMPATT diode amplifier circuit is described which uses planar microstrip circuitry. A single-diode stage serves as a driver for a four-diode combiner stage. The combiner uses a tree of three hybrids of the Wilkinson-Gysel type. GaAs double-drift IMPATT diodes are used. The device provides a minimum of 12 dB gain over a band from 9.4 to 10.6 GHz with a peak pulsed output between 105 and 120 watts over the band.

INTRODUCTION

This paper describes a new technique for obtaining broad band power amplification with IMPATT diodes in multiple-device combiner circuitry. Individual diodes are mounted in simple tuned modules which may be tested for rf performance before assembly into multiple diode combiner circuitry. Power combining is done using a "tree" of Wilkinson two-way dividers of the Gysel type. The device uses the familiar negative-resistance reflection mode of amplification with circulator coupling.

DEVICE DESCRIPTION

Fig. 1 shows a schematic block diagram of the two stage device which has been built and tested. This uses a single-diode first stage with a circulator feed. This is followed by an isolator and a four-diode second stage with circulator coupling. Fig. 2 shows a photograph of the complete device with the cover removed. Within the housings, microstrip circuitry is used to tune and couple the diodes to the outside lines.

Fig. 3 shows a schematic sketch of the diode mounting module and the method whereby it is coupled to the microstrip transmission line. This module consists of a copper stud with the diode mounted on its top face within a microstrip radial-line resonator. Multiple straps connect the cap of the diode to the resonator ring. This resonator acts as an impedance transformer to convert the very low impedance of the diode chip to a value which can adapt to the microstrip line. Coupling to this line is obtained with an overlay capacitor as shown. Further transformation is obtained by using a lower impedance section in this line adjacent to the diode.

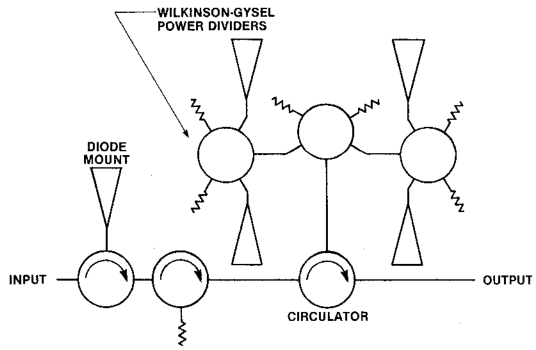

Fig. 1 Block diagram of the two-stage amplifier

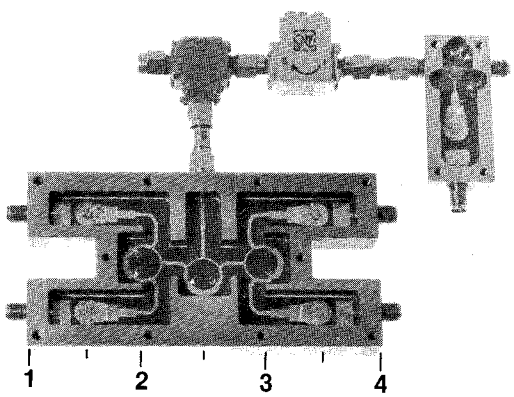

Fig. 2 The experimental amplifier with the covers removed. The input is at the upper right and the output at the upper left. The remaining connectors are for the power bias supply.

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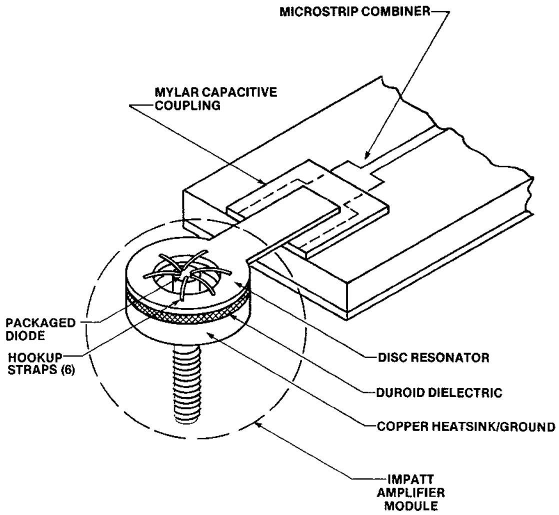


Fig. 3 Schematic sketch showing the IMPATT module and its mode of coupling to the transmission line. The copper stud is inset into the ground plane of the package.

The stud-mounted diode forms a movable "module" which is first tested and tuned in a single-diode circuit, then transferred to the combiner package. In use, the stud is mounted in the case with the top of the stud parallel and flush with the ground plane surface. Bias is applied through a fine wire bonded to the resonator as shown in the photograph. This is brought out though a capacitive section which acts as a low-pass filter.

The power-combining function is provided by the "tree" of Wilkinson dividers. The input wave is first divided by two and each half is divided again. At each diode, the waves are reflected with gain, and pass backward through the tree, recombining to emerge and be diverted by the circulator to form the final output. This combiner must have the property that the divided lines must be isolated from each other to a large degree so that waves which originate at one diode are not coupled to the others. Otherwise the diodes can reflect waves back and forth between them with gain, resulting in oscillations in modes which may not be coupled out because they are not in phase at the diodes. The Wilkinson divider has this property. We have chosen to use the Gysel variation (1) in which the resistive loads may be connected to ground and thereby be cooled for better power dissipation. A schematic diagram of this device is shown in Fig. 4. The resistive loads are necessary to achieve the desired isolation.

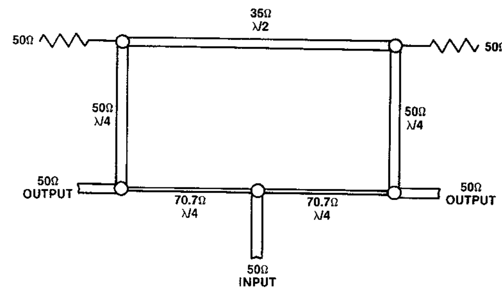


Fig. 4 Wilkinson-Gysel power divider configuration which can dissipate more power than the conventional Wilkinson divider.

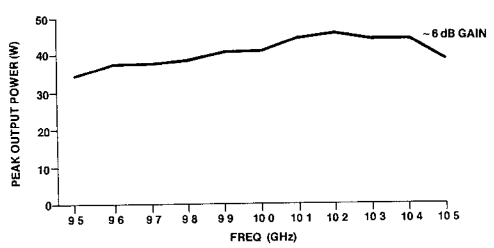
MODE OF OPERATION

To obtain broad-band amplification, it is necessary to obtain tight coupling between the diode and the coupling line. When this coupling is sufficiently strong, oscillations will be suppressed and true negative resistance amplification can be obtained. Oscillation may occur if the coupling is somewhat looser. For weak signals, high gain can be achieved over a narrow bandwidth in a stable amplifier by a suitable choice of the degree of coupling. However, because of nonlinearity, a stable IMPATT amplifier saturates gradually so that the gain will be low and the bandwidth may be much larger when it is driven sufficiently hard that maximum power output is obtained. On the other hand, an oscillator which is coupled optimally for maximum free-running power can operate as an injection-locked oscillator with high gain over a narrow bandwidth, acting thereby as an amplifier. Under these conditions, stronger drive can increase the bandwidth but this will overdrive the device and may cause excessive noise, spurious responsess or premature burn-out. We have used an intermediate degree of coupling in which the device will oscillate, but inefficiently, when no input signal is applied. With a normal rf drive level, oscillations are suppressed and wide-band "amplification" is achieved, with full power and efficiency. The principles involved are described in ref (2). In most applications for IMPATT diodes, this "pseudo-stable" mode of operation is permissible and desirable.

Our experience indicates that many of the problems associated with excessive noise and spurious instabilities in the bias circuit with IMPATT diode amplifiers and oscillators are associated with in insufficient degree of coupling to the external line as affected by the impedance transformation used. An insufficiently loaded oscillator will overdrive itself with internal rf voltages, which exceed the optimum values. An under-coupled negative-resistance amplifier can be easily overdriven with unpleasant consequences.

EXPERIMENTAL RESULTS

The device was tested at X-band with pulsed signals and pulsed "dc" applied as power bias. For the data shown in Fig. 5, the pulse length was .6 micro-sec and the duty was .16% to meet customer requirements. Longer pulse lengths and greater duty factors have been used, however, with no apparent degradation of power and efficiency. In some cases, frequency-response data was obtained with oscilloscopic display using pulsed signals. The response across the band was smooth and free of evident spurious effects. For these curves, the gain was kept constant, at 6 and 12 dB respectively, and the power output was allowed to vary as shown. The drive signal was obtained from a sweep oscillator, fed to a traveling-wave tube power amplifier through an rf switch which was pulse driven to provide a pulsed rf source.



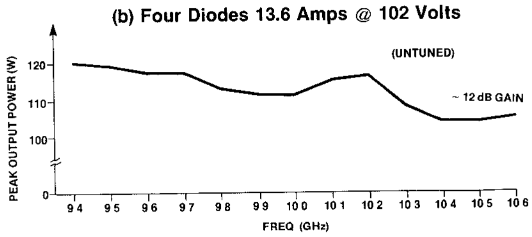


Fig. 5 Power output vs frequency curves for the single-diode stage and the two stages in tandem.

CONCLUSIONS

It has been shown that broad-band high-power pulsed amplification can be obtained with double-drift IMPATT diodes in X-band, using simple microstrip circuitry. With the use of pre-tuned module mounts for the diodes, assembly and preparation of hybrid combiners is facilitated, offering the potential of low cost manufacture.

ACKNOWLEDGEMENTS

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REFERENCES

(1) Ulrich H. Gysel, "A New N-Way Power Divider/ Combiner Suitable for High Power Applications", 1975 S-MTT International Symposium, Digest of papers, pp 116-118.

(2) M. E. Hines, "Negative-Resistance Diode Power Amplification" IEEE Trans. Electron Devices, ED-17, 1, Jan 1970, pp 1-8.