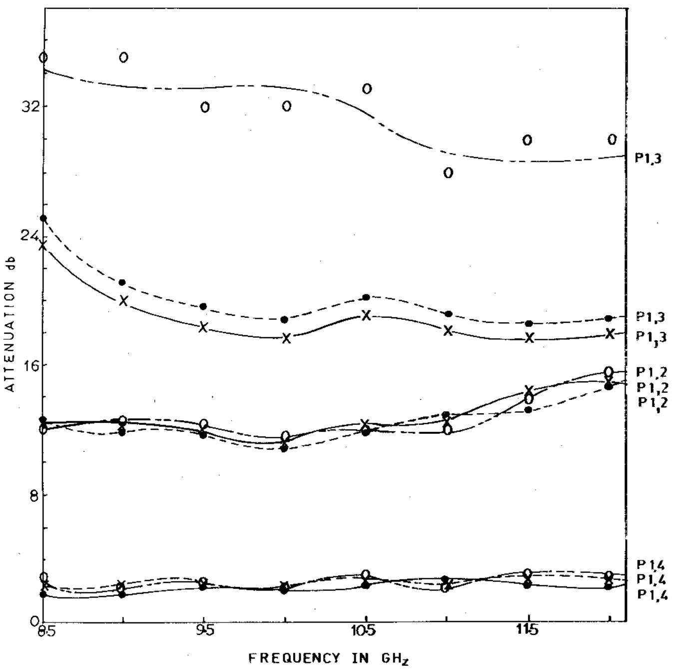

Fig. 2. Plot of transmission measurements ports 1–2 ($P_{1,2}$), 1–3 ($P_{1,3}$), and 1–4 ($P_{1,4}$) for the 12-dB directional coupler. Legend: -o- - - -o- with overlay of 8450 Å Bi_2O_3. - - • - - • - -with overlay of 3900 Å Bi_2O_3. —×— —×— without overlay.

isolation, may have been due to the presence of an air gap (though lesser now) between the two microstriplines in the coupled region and the consequent incomplete confining of the fringing field through the dielectric. It may be pointed out that no allowance was made for the change in impedance due to overlay and the effect of overlay on dispersion characteristics in the design of the coupler.

References

[1] A. Schwarzmann, "Approximate solutions for a coupled pair of microstrip lines in microwave integrated circuits," *Microwave J.*, pp. 79–82, May 1969.
[2] T. G. Bryant and J. A. Weiss, "Parameters of microstrip transmission lines and coupled pairs of microstrip lines," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-16, pp. 1021–1027, 1968.
[3] H. A. Wheeler, "Transmission line properties of parallel strips separated by a dielectric sheet," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-13, pp. 172–185, Mar. 1965.
[4] R. N. Karekar and M. K. Pande, "Effect of thin film Bi_2O_3 overlay on the quality factor of a microstrip resonator," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-24, pp. 262–264, May 1976.
[5] B. E. Spielman, "Analysis of electrical characteristics of edge coupled microstrip lines with a dielectric overlay," Naval Res. Lab., Washington, DC, NRL Report 7810, Oct. 25, 1974.
[6] G. Haupt and H. Delfts, "High-directivity microstrip directional couplers," *Elect. Lett.*, vol. 10, pp. 142–143, May 2, 1974.

Symmetry Experiments with Four-Mesa IMPATT Diodes

C. T. RUCKER, G. N. HILL, N. W. COX, AND J. W. AMOSS

***Abstract*—Experiments with four-mesa silicon p^+-n-n^+ IMPATT diodes have shown power saturation and reduced efficiency when connected and packaged in electrically asymmetrical configurations. The need for electrical symmetry is illustrated by experiments wherein seemingly trivial asymmetries caused severe saturation of the power output.**

Manuscript received February 6, 1976; revised May 3, 1976. This work was supported by the Air Force Avionics Laboratory.
The authors are with the Solid State Sciences Division, Engineering Experiment Station, Georgia Institute of Technology, Atlanta, GA 30332.

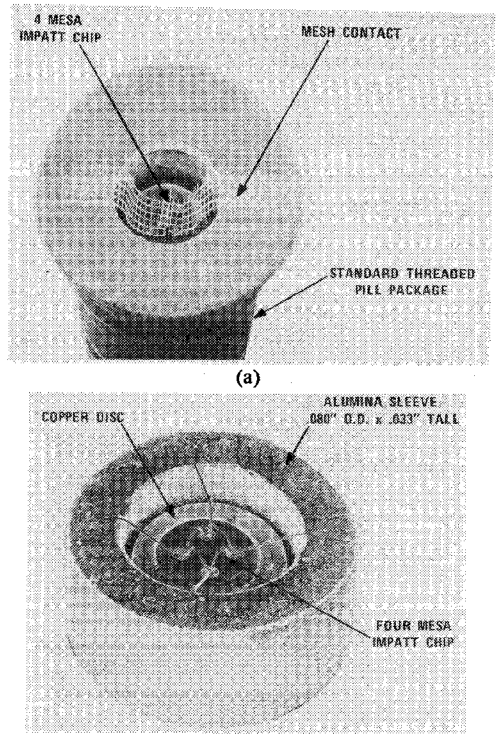

Fig. 1. (a) SEM of four-mesa IMPATT diode with mesh contact. (b) SEM of four-mesa IMPATT diode with multiple wire contacts (after Fig. 2, case IV).

Four-mesa IMPATT devices with integral plated heat sinks have become relatively common as a means of increasing power output (device area) without serious degradation of the device thermal properties [1], [2]. These devices are usually contacted in a symmetrical fashion using one or more gold ribbons, wires, or mesh segments. A typical configuration of this type is shown in the scanning-electron-microscope micrograph (SEM) of Fig. 1(a). During efforts to study the effect of impedance on efficiency very uniform four-mesa silicon p^+-n-n^+ devices were tested in a somewhat different configuration [Fig. 1(b)] with one, two, three, and then all four mesas connected. The resulting total junction capacitances at breakdown were 0.22, 0.44, 0.66, and 0.88 pF, respectively. For the devices used no change in efficiency was observed if the current density remained constant.

More significantly, these tests provided an unexpected insight into the operation of parallel chips. The initial mesa connections were made as shown in Fig. 2, cases I–IV. All the sketches of Fig. 2 represent various modifications of the detailed construction shown in Fig. 1(b). Cases I, II, and IV behaved exactly as expected giving one, two, and four times the power expected from one mesa at the same current density. Case III did not behave as expected. Instead, this case saturated at less than half the appropriate current density. The saturation was characterized by noisy output and broad-band noise between 0 and 2.0 GHz, but coherent spurious outputs were not observed. Case III was modified as shown in III-A where the diagonal interconnecting wire was added. This change, to a more symmetrical arrangement, resulted in satisfactory operation at higher current but satura-

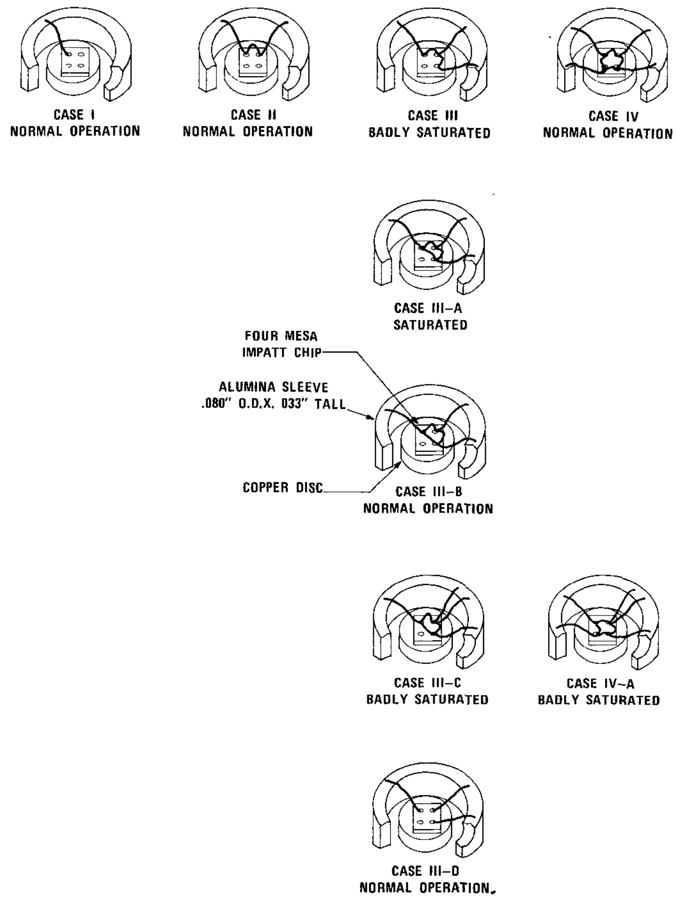

Fig. 2. Sketches showing four-mesa IMPATT diode with symmetrical and asymmetrical wire connections.

tion still occurred at a current density below that of I, II, or IV. Noting that the diagonal wire of III-A was approximately $\sqrt{2}$ times as long as the adjacent wires, it was decided to decrease the length of the diagonal wire by about 40 percent. This was accomplished by replacing the curved diagonal wire with a straight wire, giving the configuration of III-B. The configuration then did not exhibit saturation or low-frequency noise at any current density. Subsequent tests, where asymmetry was intentionally introduced in cases III and IV, also showed the saturation and noise described previously. Two such configurations are indicated by cases III-C and IV-A. A final test, III-D, where no interconnecting leads were used, performed without saturation or noise.

None of the saturation effects described (except for III-C and IV-A) would be expected based on fundamental frequency considerations. This assertion is based on the following factors.

1) The chips were fabricated at the same time, by the same process on a common heat sink.

2) No difference in either capacitance or breakdown voltage could be measured between the four devices using standard bridge and curve-tracer techniques.

3) The mesa spacing (0.016 center to center) is so small that the inductance due to the wire(s) connecting the mesas is on the order of 0.2 nH, a value much too small to allow fundamental frequency resonant effects among the respective devices.

4) Given 1)–3), the fundamental frequency voltages would be of the same amplitude and phase at each device as would the currents, resulting in negligible interaction among the devices at the fundamental frequency even in the presence of asymmetrical interconnections.

Conversely, the mesa spacing *is* large enough to permit resonance at the third or fourth harmonic. It is therefore suggested that the effects observed are probably a result of harmonic current components flowing among the devices via the interconnecting wires but not observed in the output. The aggregate conclusion suggested by these tests is that seemingly trivial asymmetry of the parasitic elements used in the device interconnection can result in gross saturation of the output power and in low-frequency noise.

Acknowledgment

The authors wish to thank R. T. Kemerley, program monitor, for his assistance. They are grateful to the United States Air Force for permission to publish this material.

References

[1] J. Frey, "Multimesa versus anular construction for high average power in semiconductor devices," *IEEE Trans. Electron Devices*, vol. ED-19, pp. 981–985, Aug. 1972.
[2] J. C. Irvin, "GaAs IMPATT diodes in perspective," in *Proc. Fourth Biennial Cornell Electrical Engineering Conference*, 1973, pp. 287–298.

Comments on "A New Edge-Mode Isolator in the Very High Frequency Range"

ROBERT A. CRAIG

Abstract—**Test data taken on production models of fixed-tuned isolators operating in the 225–400-MHz frequency range are presented for comparison to those given in the referenced paper. Better electrical performance of this isolator as well as a smaller size compared to the edge-mode unit is shown.**

In a recent paper,[1] Courtois *et al.* presented a novel approach to constructing an isolator in the VHF frequency range, but have obviously overlooked some of the prior work in this field. For example, in their introduction, the statement, "Until now, two conventional devices were necessary to cover this overall bandwidth," is not correct. Addington Laboratories, Inc., first completed a single broad-band unit to cover this frequency range without tuning in January 1973. It has been advertised in our ferrite device catalog for nearly two years.

Production models of this device were first tested in March 1975. We believe our specifications are better than those reported in the referenced paper and have listed them as follows, along with those of the unit described in the paper for ease of comparison. Neither unit is magnetically tuned.

Manuscript received June 28, 1976.
The author is with Addington Laboratories, Santa Clara, CA 95050.
[1] L. Courtois, N. Bernard, B. Chiron, and G. E. Forterre, *IEEE Trans. Microwave Theory Tech.*, vol. MTT-24, pp. 129–135, Mar. 1976.