H-1

A mm-WAVE MICROSLAB™ OSCILLATOR

H.B. Sequeira and J.A. McClintock

Martin Marietta Laboratories
Baltimore, Maryland

ABSTRACT

We report, for the first time, a mm-wave GaAs Gunn device directly coupled to a novel planar transmission medium, Microslab.™ A monolithic-like structure was used to couple the GaAs device to a GaAs Microslab network to produce 0.25 mW at 141 GHz.

INTRODUCTION

Microslab† is a low-loss, low-dispersion, wideband planar waveguiding medium that offers significant advantages for mm-wave monolithic circuits at frequencies beyond 60 GHz. For example, at 94 GHz, Microslab has shown (1) line losses of 0.16 dB/cm -- a factor of 8 lower than a competitive microstrip line -- while retaining reasonably low dispersion.

In a mm-wave monolithic circuit, it is very desirable to integrate power-generating sources, such as a local oscillator, on the GaAs (or other semiconductor) chip. Therefore, it is necessary to demonstrate the monolithic compatibility of Microslab by successfully coupling a power device into it. Furthermore, this coupling should be performed preferably without the intermediary of a waveguide or other similar "cover."

We describe the design, fabrication, and testing of a mm-wave GaAs Gunn oscillator built around a packaged device intended for harmonic extraction service. Although a discrete device was used, the design was constrained to approximate monolithic conditions.

BACKGROUND

Microslab derives its name from micro-strip and dielectric slab waveguide because it embodies their transmission properties. Figure 1 illustrates the geometry and permittivities of the structure. The dielectrics and their thicknesses are chosen such that the propagating energy is in a single mode confined to the central dielectric, ε_g, at the upper range of the frequency spectrum of interest. In this range, the coupling to the metal conductors is via the evanescent tails of the propagating mode. The field strength is thus lowered at the conductors, and ohmic losses are reduced.

† Patent pending

Coupling to the conductors increases only at lower frequencies where ohmic losses are low. Furthermore, this increased coupling causes the mode to become increasingly microstrip-like in nature, thereby lowering dispersion below that of a slab waveguide. A judicious choice of dielectric materials and geometry can produce wideband single-mode propagation with low loss and low dispersion.

APPROACH

To emphasize monolithic feasibility, the Microslab structure of Fig. 1 was fabricated using a semi-insulating single crystal <100>-oriented GaAs substrate as the guiding layer ε_g. An alumina slab and rod, with permittivity, ε_s, and metallized as shown, formed the other elements of the structure. The dimensions were chosen for single-mode operation up to 150 GHz and were optimized to minimize loss and dispersion over this range.

The cross-sectional dimensions of the structure are shown in the inset of Fig. 2, which also displays the corresponding dispersion of the fundamental mode for frequencies up to the cutoff for the next higher-order mode. The upper and lower dashed curves correspond to the cases where the width, w, of the metallized dielectric rod is infinite and zero, respectively. The solid curve corresponds to the line width actually used in the oscillator design. As shown, the effective dielectric constant for the propagating mode varies between 8.92 ε_0 and 10.76 ε_0 for w = 0.25 mm, and the loss (not shown) was computed to be 0.1 dB/cm. Wider lines are less dispersive but limited by transverse-mode considerations. A narrower line displays larger dispersion, but more significantly, higher dispersion sensitivity to variation in line width. The width for the oscillator design was selected for tolerable sensitivity consistent with reasonable device match.

The circuit design, shown in Fig. 3. was deliberately constrained such that the Gunn diode chip within the package was in the plane of one of the GaAs faces of the Microslab structure (again, to closely approximate the monolithic situation). A resonant ring was positioned along the line for impedance matching and frequency definition, using considerations similar to those applied to microstrip DRO oscillators (2). The final position of the ring and its separation from the Microslab line was determined experimentally so as to maximize the output power.

To test the oscillator, a cosine-tapered ridge transition (3) was made to rectangular waveguide.

FABRICATION & TEST

The skin depth of mm-wave energy at the operating frequency is approximately 0.2 μm. Therefore, the metallized interfaces must be highly polished to realize the low loss. The alumina elements were obtained by grinding and polishing 99.6% alumina slabs to the proper thickness and finish, and then cutting and machining the desired alumina elements. These parts were then metallized and epoxy-bonded to the vendor-supplied GaAs substrate. The composite structure was then soldered to a gold-plated brass block which contained the diode and the waveguide transition. Initially, we designed the circuit to accommodate two resonant rings, one at the fundamental and the other at the second harmonic. However, due to difficulties in fabricating these and other elements, the design was modified, and additional off-chip tuning was added. Figure 4 is a picture of the actual oscillator circuit.

The Gunn device produced about 0.25 mW of power at 141 GHz, corresponding to the third harmonic of the device. The device did not oscillate when the resonant rings were removed, thus demonstrating that the on-chip elements were the primary determinants of circuit behavior. Alumina rods with some metallization spillover on their vertical walls were also used in some structures with no significant effect on the oscillator output power or frequency. Other oscillator measurements are planned in the future.

CONCLUSIONS

We have successfully demonstrated a Gunn oscillator using Microslab, a novel low-loss, low-dispersion waveguiding medium for mm-wave applications. We believe that this is the first demonstration of direct (i.e., without the use of rectangular waveguide or its derivatives) launching of power into any planar dielectric waveguide from a discrete device above 90 GHz. Design data have been presented for calculating the Microslab propagation constant at different operating frequencies. Although we attempted to closely approximate a monolithic design within the fabrication constraints, significant challenges lie ahead. We are concurrently investigating related materials, thermal, and processing requirements necessary for a fully integrated monolithic circuit implementation.

ACKNOWLEDGEMENT

The authors thank Steve Brown for assembling the oscillator circuit.

REFERENCES

(1) H.B. Sequeira and J.A. McClintock, presented at the 5th Benjamin Franklin Symposium, Philadelphia, PA, 4 May 1985.

(2) M. Dydyk and H. Iwer, "Planar IMPATT diode oscillator using dielectric resonator," Microwaves & RF, vol. 23, no. 10, pp. 135ff, Oct 1984.

(3) D.R. Singh and C.R. Seashore, "Straightforward approach produces broadband transitions," Microwaves & RF, vol. 23, no. 9, pp. 113ff, Sept 1984.

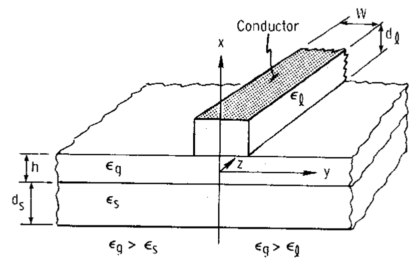

Figure 1. The Microslab™ structure.

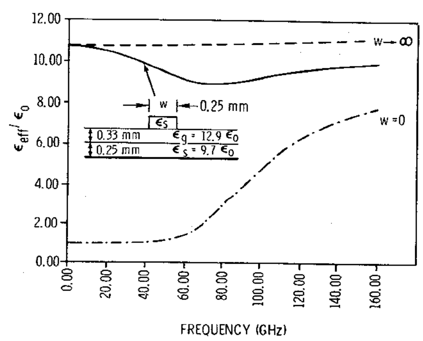

Figure 2. Microslab dispersion for the dimensions and permittivities (inset) selected.

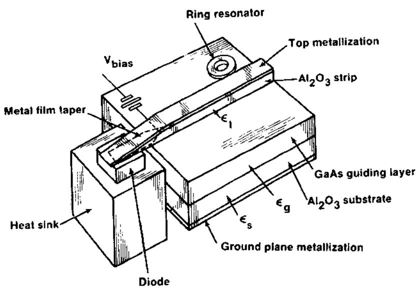

Figure 3. mm-wave Microslab oscillator circuit.

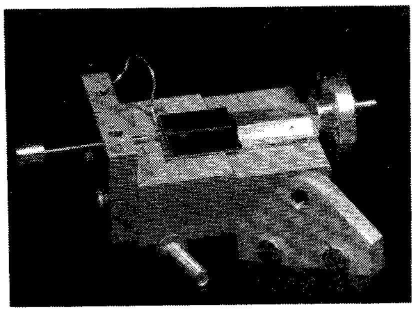

Figure 4. Partially disassembled mm-wave oscillator circuit (actual size).