MINIATURE MILLIMETER-WAVE INTEGRATED CIRCUIT WIDEBAND DOWNCONVERTERS

Albert Grote, Raghbir S. Tahim, and Kai Chang

TRW Electronics and Defense
One Space Park
Redondo Beach, CA 90278

ABSTRACT

The miniature millimeter-wave integrated circuit LO/mixer assembly was developed with over the full waveguide band coverage and good temperature stability. A conversion loss of less than 7 dB was achieved over 16 GHz instantaneous IF frequency with the RF swept from 30 to 46 GHz and the LO at 48 GHz. With another mixer, when the RF was swept from 18 to 30 GHz and the LO was at 32 GHz, similar results were achieved. Using resonant stub and dielectric temperature compensation produced good temperature stability.

INTRODUCTION

Broadband downconverters are required for many receiver systems. Integrated circuits, essential to achieve small size, light weight, and low cost, also have the potential of direct translation into monolithic circuits and for large-scale integration.

Broadband mixers were recently reported at W- and D-band using suspended stripline and finline structures with 20 to 30 percent bandwidth [1-3]. This paper reports crossbar suspended stripline mixers with over full waveguide bandwidth coverage. The mixer was integrated with a microstrip Gunn oscillator in a very compact package with a size of less than 1 cubic inch. The Gunn oscillator was temperature-compensated using dielectric material to achieve a stability of ±2 ppm/°C. With the LO at 48 GHz, a conversion loss of less than 7 dB was achieved over the RF frequency range of 30 to 46 GHz. Similar results were achieved with the LO at 32 GHz and the RF swept from 18 to 30 GHz.

GUNN OSCILLATORS

Figure 1 shows the schematic of a microstrip Gunn oscillator fabricated on 0.010-inch Duroid substrate with a dielectric constant of 2.22. The diode package reactances were tuned out with a stub resonator, which was also used to stabilize the oscillating frequency. A quarter-wavelength matching transformer was used for impedance matching to set the impedance seen by the diode. Frequency stability was achieved with a dielectric disk mounted next to the line approximately a quarter-wavelength behind the matching transformer. The barium tetratitanate dielectric material was selected with a temperature coefficient opposite that of the Gunn oscillator; the results are shown in Figure 2. Frequency stability of ±2 ppm/°C was achieved with a dielectric temperature compensation over 0 to 30°C temperature range; without dielectric temperature compensation, frequency stability of ±10 ppm/°C was observed. This is still better than the results obtained for waveguide (±20 ppm/°C) due to the high-Q stub resonator circuit. A highest output power of 100 mW was achieved at 48 GHz using the diode rated at 150 mW in a waveguide circuit. Figure 3 shows a photograph of this Gunn oscillator.

A Gunn VCO is desirable to electrically achieve fast frequency tuning for some applications. The circuit shown in Figure 1 can be modified by incorporating a varactor diode behind the Gunn diode for tuning purposes. As shown in Figure 4, a varactor tuning range of more than 1 GHz was achieved with over +16 dBm output power at the center frequency of 47.5 GHz.

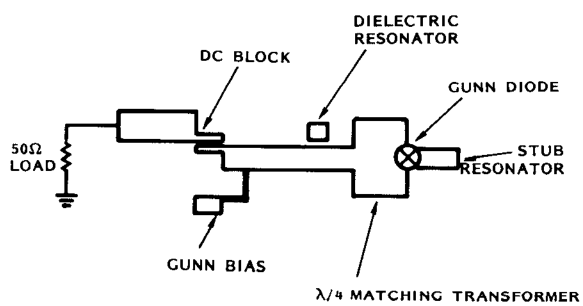

Figure 1. Microstrip Gunn oscillator circuit configuration.

0149-645X/85/0000-0159 $01.00 © 1985 IEEE

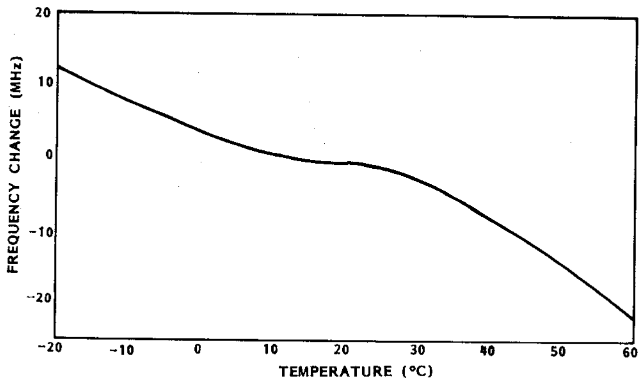

Figure 2. Frequency stability of temperature-compensated Gunn oscillator.

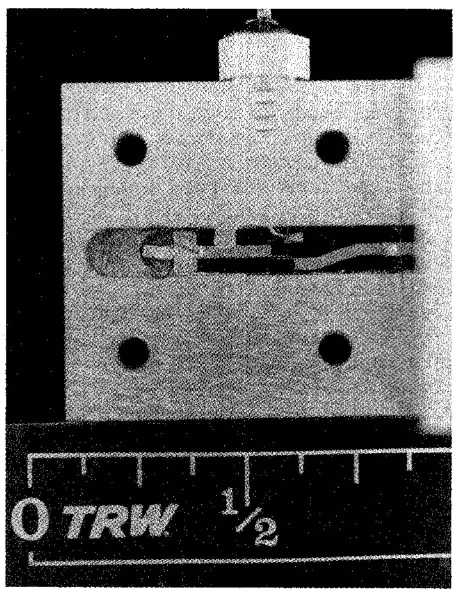

Figure 3. Microstrip Gunn oscillator.

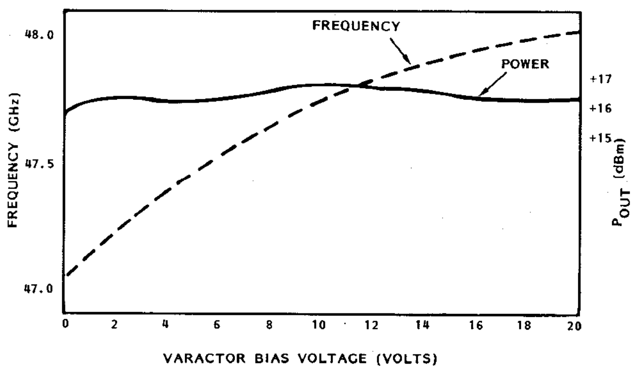

Figure 4. Power output and frequency as a function of varactor bias voltage.

MIXERS

The crossbar mixer was chosen for its broadband and low conversion loss [1]. The basic configuration of the crossbar stripline mixer is shown in Figure 5. The LO power is coupled to the diodes via a broadside coupler optimized for broadband operation. The RF signal is applied to the mixer diodes from a waveguide perpendicular to the circuit board. The crossbar configuration is formed by two mixer diodes with opposite polarity connected across the broadwalls of the waveguide. The mixer diodes are thus in series with respect to the RF signal and in parallel with respect to the IF cicuit. The IF signal is extracted via a lowpass filter.

A broadside coupler in the LO path is designed to present an open circuit to the IF frequencies to prevent dissipation of IF power in the LO port. The coupler also serves as a dc block as the mixer is integrated with an MIC local oscillator. The RF signal is matched to the diode impedance by a reduced-height step transformer. The junction resistance, R , of the mixer diode is varied with the LO pump and can be as low as 100 to 150 ohms under fully turned-on conditions. Waveguide impedance is in the range of 400 to 600 ohms. Since the two diodes are in series with respect to the RF circuit, matching the RF is easily accomplished through a step-reduced height transformer.

DOWNCONVERTER INTEGRATION

Figure 6 shows a photograph of the LO/mixer assembly*. On the right of the picture is the Gunn oscillator. The output of the Gunn oscillator was coupled to the mixer through the broadside coupler described in reference 1. The location of the broadside coupler was optimized to achieve broadband operation.

The inclusion of a microstrip local oscillator does not increase the size of the crossbar stripline mixer. In contrast, it reduces the size of the mixer because the probe transition used to couple the LO power from the local oscillator to the mixer is eliminated. The size of the downconverter is less than 1 cubic inch.

DOWNCONVERTER PERFORMANCE

The performance of the downconverters was fully evaluated. Figures 7 and 8 show the conversion loss as a function of the RF frequency. With the LO fixed at 48 GHz, a conversion loss of less than 7 dB was achieved as the RF was swept from 30 to 46 GHz. The IF output was 2 to 18 GHz. Similar results were also achieved from another unit with the LO at 32 GHz and the RF swept from 18 to 30 GHz. The RF bandwidth exceeds the full waveguide bandwidth. For narrow bandwidth, a conversion loss of 4 to 5 dB was achieved.

Figure 9 shows the results of intermodulation measurements. The third order intercept point is around +20 dBm (input). The 1-dB compression point is at +12 dBm, and LO/RF isolation is over 25 dB.

*Patent pending.

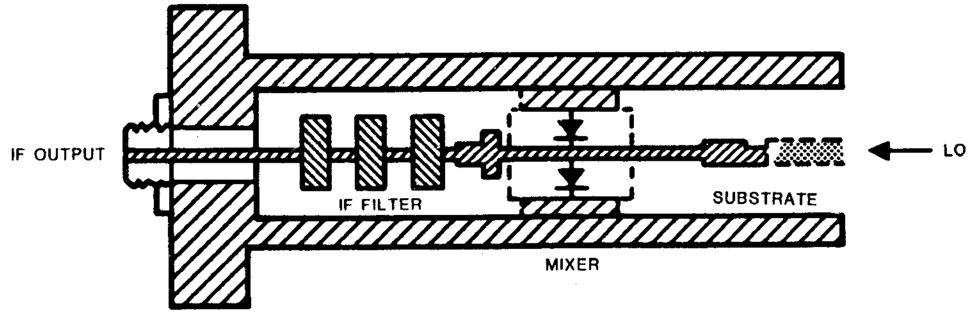

Figure 5. Crossbar stripline mixer.

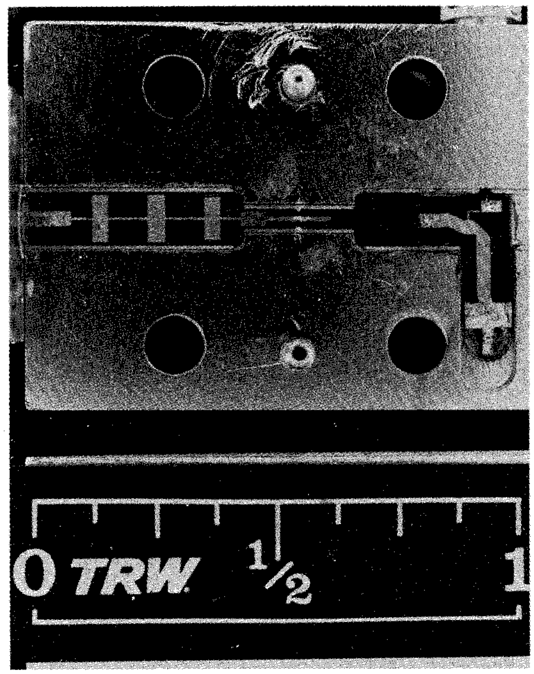

Figure 6. LO/mixer assembly.

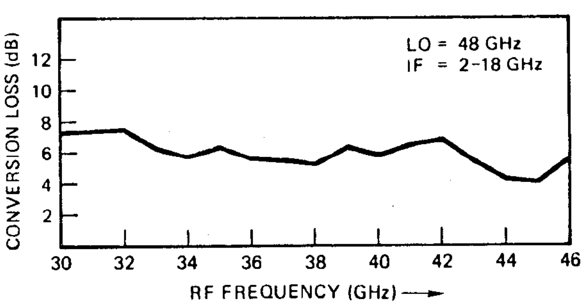

Figure 7. Performance of downconverter with LO at 48 GHz.

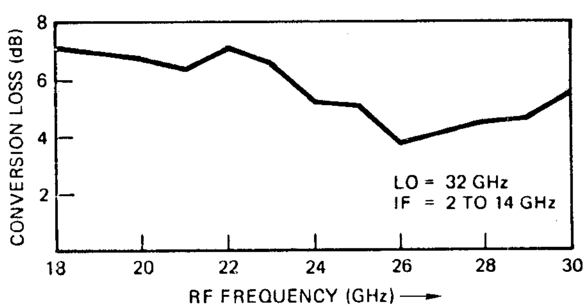

Figure 8. Performance of downconverter with LO at 32 GHz.

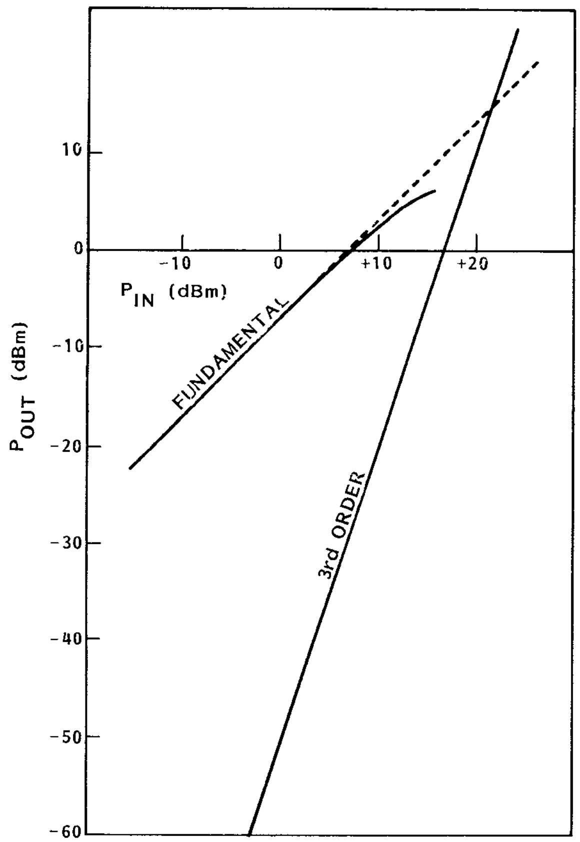

Figure 9. Intermodulation measurement for downconverter.

CONCLUSIONS

A miniature downconverter assembly consisting of the LO and mixer was developed using integrated circuits. The unit operates at very wide instantaneous RF bandwidth. The LO was designed to have good temperature stability using the resonant stub and dielectric temperature compensation method.

ACKNOWLEDGMENT

The authors wish to thank Drs. C. Sun and T. Fong for their constant encouragement. They would also like to thank Mr. T. Pham, Mr. D. English, and Ms. T. Cazares for technical assistance.

REFERENCES

1. R. S. Tahim, G. M. Hayashibara, and K. Chang, "Design and Performance of W-band Broadband Integrated Circuit Mixers," IEEE Trans. on Microwave Theory and Tech., Vol. MTT-31, March 1983, pp. 277-283.

2. R.S. Tahim, T. Pham, and K. Chang, "W-band Low Noise Integrated Circuit Crossbar and Finline Mixers with Over 20 GHz Instantaneous RF Bandwidth," 1983 IEEE-MTT Microwave Symp. Digest Tech. Papers, May 1983, pp. 290-292.

3. C. Nguyen and K. Chang, "140 GHz Broadband Crossbar Stripline Mixers with over 20 GHz Instantaneous RF Bandwidth," Electronics Letters, Vol. 20, No. 11, May 24, 1984, p. 441.