A Resonant Tunnelling Diode Self-Oscillating Mixer with Conversion Gain

Garry Millington, Robert E. Miles, *Member, IEEE,* Roger D. Pollard, *Senior Member, IEEE,* D. Paul Steenson, and J. Martyn Chamberlain

Abstract—**An 11 GHz self-oscillating microwave mixer using a resonant tunnelling diode has been constructed. Operating in a non-optimised system a maximum conversion gain of 10 dB with an associated noise figure of 11.5 dB has been observed. As a result of the conversion gain and self-oscillating configuration, a simpler construction with fewer components than conventional circuits is obtained. The local oscillator can be injection locked and swept over a frequency range of 200 MHz.**

I. Introduction

The strong nonlinearity and negative differential resistance (NDR) inherent in the current voltage characteristic of a resonant tunnelling diode (RTD) makes it a suitable device for mixer and multiplier applications [1]. A self-oscillating mixer configuration has been demonstrated [2] but this utilised a third harmonic local oscillator (LO) signal. This letter describes a practical self-oscillating mixer circuit operating with a fundamental local oscillator signal in the 11 GHz region generated by a 20 micron diameter RTD. The same RTD also acts as the mixing element of the circuit and as the overall system exhibits conversion gain it represents a much simpler configuration than that associated with, say, a Schottky diode mixer.

II. Experimental

The resonant tunnelling diode used in this work was grown at Nottingham University with the double barrier layer structure shown in Fig 1. This structure produced a peak-to-valley current ratio of 2:1 and a peak current density of 2.5 $kAcm^{-2}$. It was bonded into an S4 package that was in turn mounted in a tunable X-band waveguide cavity. The RF signal derived from a sweep oscillator was introduced via a waveguide circulator and the intermediate frequency (IF) was extracted from the diode bias circuit. A three-stub tuning element mounted between the cavity and circulator was used to optimize the conversion efficiency. The setup is illustrated in Fig. 2 that also shows how the LO signal from the diode can be observed on a second spectrum analyzer connected to the third port of the circulator.

Manuscript received April 30, 1991; revised June 28, 1991. This work was supported by the SERC through the NUMBERS project.

G. Millington, R. E. Miles, and R. D. Pollard are with the Department of Electronic and Electrical Engineering, University of Leeds, Leeds LS2 9JT, England.

D. P. Steenson and J. M. Chamberlain are with the Department of Physics, University of Nottingham, University Park, Nottingham NG7 2RD, England.

IEEE Log Number 9103566.

0.5 µm	GaAs	1×10^{18} cm^{-3}
0.1 µm	GaAs	1×10^{17} cm^{-3}
5.1 nm	GaAs	*undoped*
4.2 nm	AlGaAs	*undoped*
5.1 nm	GaAs	*undoped*
4.2 nm	AlGaAs	*undoped*
5.1 nm	GaAs	*undoped*
0.1 µm	GaAs	1×10^{17} cm^{-3}
2 µm	GaAs	1×10^{18} cm^{-3}
	n^+ GaAs substrate	

Fig. 1.

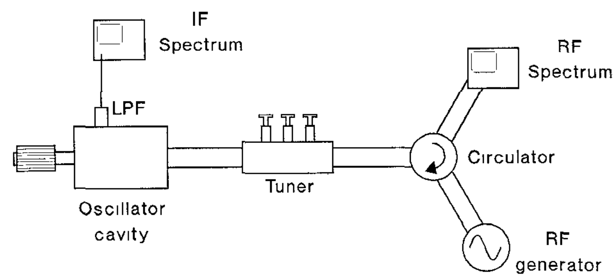

Fig. 2.

III. Results

Fig. 3(a) shows a typical IF output signal at 39.5 MHz resulting from the RF and LO signals at 10.9083 GHz and 10.9478 GHz respectively shown in Fig. 3(b). The down-converted frequency can be varied over a range of about ± 20 MHz by changing the bias on the RTD or over a wider range of 200 MHz by changing the frequency of the RF signal input. While a conversion gain of about 4 dB could be maintained over the full bandwidth, a peak of 10 dB was observed over a smaller range of ± 10 MHz at an IF of 50 MHz by matching the RF signal to the RTD using the three stub tuner.

The single side-band noise figure of the mixer circuit has been measured using a calibrated noise source and noise figure meter and found to be 11.5 dB with a conversion gain of 10 dB. These figures were obtained using filtering of the input noise in order to reduce the contribution of spurious

1051-8207/91$01.00

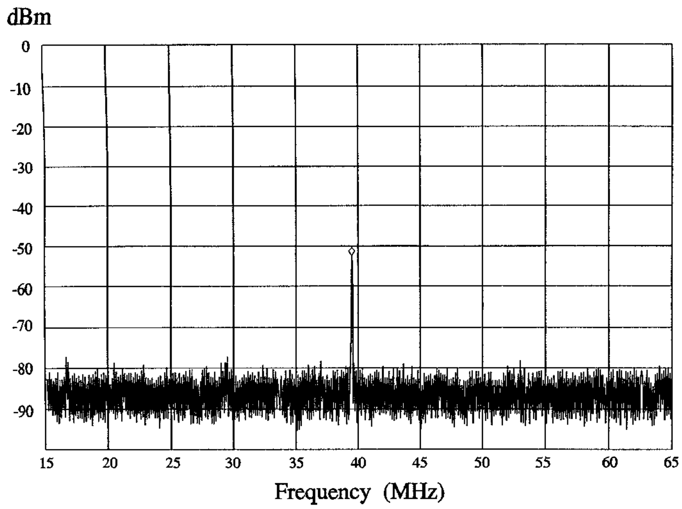

Fig. 3(a).

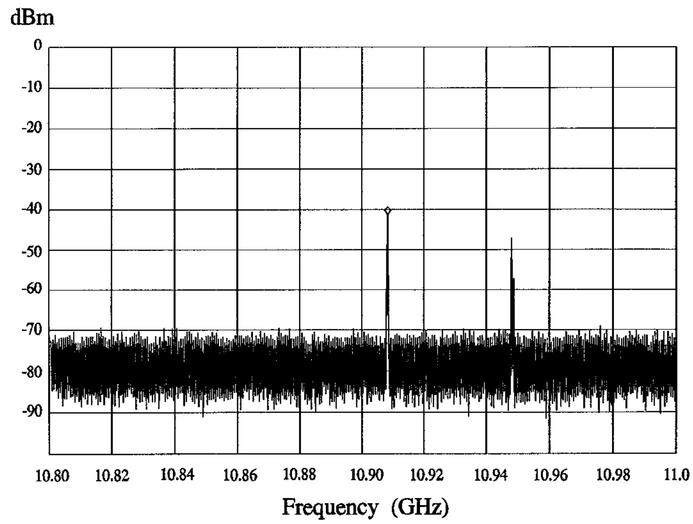

Fig. 3(b).

in-band signals from the RTD being mixed down and adding to the IF noise already present.

In a variation of this circuit, shown in Fig. 4, the sweep oscillator was fed into the cavity via a waveguide coupler and the RF signal was received by a horn antenna. In this arrangement, the oscillation frequency produced by the RTD could be injection locked and swept over a range of 200 MHz.

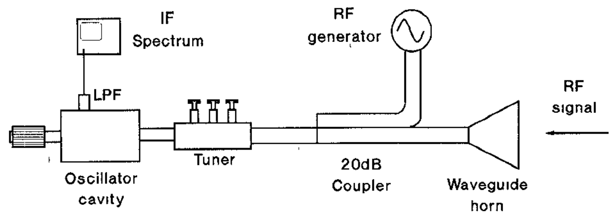

Fig. 4.

IV. Conclusion

The microwave results described show how a resonant tunnelling diode can be used as an efficient self-oscillating mixer with a performance comparable to that of a more conventional system, but with considerably less complexity. While the RF circuits used here have been matched using a single tuning element, it is expected that the performance can be improved considerably by more rigorous circuit design employing a large signal equivalent circuit model for the device [3] and by optimizing the layer structure in the RTD. The noise figure obtained could be further improved by the use of better filtering to prevent low frequency signals adding to the IF noise. Also, as resonant tunnelling diodes have been reported as oscillating up to 600 GHz [1] it is likely that these circuits will find wide application. The ability to injection lock and sweep the local oscillator makes the mixer circuit reported here particularly suitable for FM-CW radar systems.

Acknowledgment

The authors would like to thank M. Davies and G. Hill of Sheffield University for processing assistance and M. Henini of Nottingham University for layer growth.

References

[1] T. C. L. G. Sollner, E. R. Brown, C. D. Parker, and W. D. Goodhue, "High-frequency applications of resonant-tunnelling diodes," in *Electronic Properties of Multilayers and Low Dimensional Semiconductor Structures,* J. M. Chamberlain, L. Eaves and J. C. Portal, Eds. New York: Plenum Press, vol. 231, NATO ASI Series B, 1989, pp. 283–296.

[2] A. Mortazawi, V. P. Kesan, D. P. Neikirk, and T. Itoh, "A self-oscillating QWITT diode mixer," *Proc. 19th European Microwave Conf.* Sept. 1989, pp. 715–718.

[3] R. E. Miles, G. Millington, R. D. Pollard, D. P. Steenson, J. M. Chamberlain, and M. Henini, "An accurate equivalent circuit model of resonant tunnelling diodes," *Electron. Lett.*, vol. 27, no. 5, pp. 427–428, 1991.