Injection locked self-oscillating mixers for terahertz focal plane arrays

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Terahertz imaging based on space-borne focal plane arrays has many potential applications. The challenge in implementing such arrays is the requirement for sufficient local oscillator power to achieve good conversion efficiency and noise figures from a large number of mixers. An attractive solution to this problem is the use of self-oscillating mixers which are injection locked to single local oscillator that provides a weak drive to each mixer.

We have already reported injection locking of room-temperature oscillations in structures in which a number of resonant tunneling diodes are connected at regular intervals to a transmission line. The use of resonant tunnelling diodes in these structures offers the possibility of extending their operation towards 1 THz, particularly because many of the parasitics become part of the transmission line structure. This paper reports the further work in which the conditions for these circuits to be used as mixers has been explored. Our results show many interesting features: in particular injection locking and mixing have been observed experimentally with very low levels (<-20 dBm) of local oscillator signal.

The use of such mixers poses some interesting problems which we have investigated using a number of theoretical models. The results of these will be discussed in this paper. The natural oscillation frequency of a transmission line with several (4 - 10) active devices is close to its cut-off frequency. As a result the structure shows strong dispersion and a very low effective impedance. The use of these structures as mixers requires that the self-generated local-oscillator signal and the received signal have similar relative phases on all active devices. In the presence of strong dispersion the range of frequencies for which this is true is severely limited. In a similar way the very low impedance of the structure makes effective matching of the received signal to it difficult. A solution to both these problems is to operate the structure at a frequency significantly (~5%) below that of the the natural oscillations. This results in a considerable reduction of the problems associated with bandwidth and impedance matching, but requires greater injection-locking power.

A second issue with the application of these structures as mixers is the current-voltage characteristic of the resonant tunnelling diodes. It is possible for a diode to have a negative resistance characteristic, and hence generate the required oscillations, without having the quadratic features that are necessary to achieve good mixing behaviour. This is particularly a problem with diodes operated at room temperature and with those where series resistance is significant.

The paper will present estimates for the potential performance, both in terms of conversion efficiency and the required injection locking power, over a range of frequencies up to 1 THz.