HIGHLY RELIABLE LOW-NOISE MM-WAVE MIXERS

WITH WHISKER-CONTACTED HONEYCOMB DIODES

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Abstract

Single ended mixers at 94 GHz and 140 GHz with whisker-contacted honeycomb diodes have been realized. Environmental tests showed that the split block mixermount construction withstands shocks up to 1000 g/2 ms. Commercially available Mott-diodes have been used to obtain noise temperatures of 600°K (SSB) at 94 GHz and 250 uW L.O. drive.

Introduction

Numerous publications during the last years showed, that whisker-contacted GaAs-Schottky-barrier diodes are devices suited for realizing mixers with excellent data in the millimeter and submillimeter region.[1]

It is commonly said that whisker-contacted diode mixers are mechanically sensitive devices. It also seems that a diode with outstanding performance is a single-piece work.

This paper reports on a mixer design that satisfies Mil-specifications and that has excellent noise performance using commercially available Schottky-barrier mixer diodes.

Mixermount

The mixermount, similar to that proposed by Kerr et al[2] in 1977 consists of two parts: the wafer - a reduced hight waveguide section that carries the IF-choke and the diode post, and the wafermount. The wafer is a split brass block construction as shown in Figure 1. A 9 element lowpass filter[3] deposited on a 110 µm quartz substrate is used as an IF-choke. The first element of the filter carries the whisker. The whisker material is a phosphore bronce wire, 12,5 µm thick, pointed to a tip of less than 2 µm of diameter and finally gold plated using a commercial plating solution (Solrex: Antronex N). This way we get a very good and stable contact.

The substrate with the mounted whisker on it is glued into one of the wafer halves. After mounting together these two parts the diode post with the Schottky diode chip is pressed into the mount to contact one of the diodes. Figure 2 shows a close-up of the contact area.

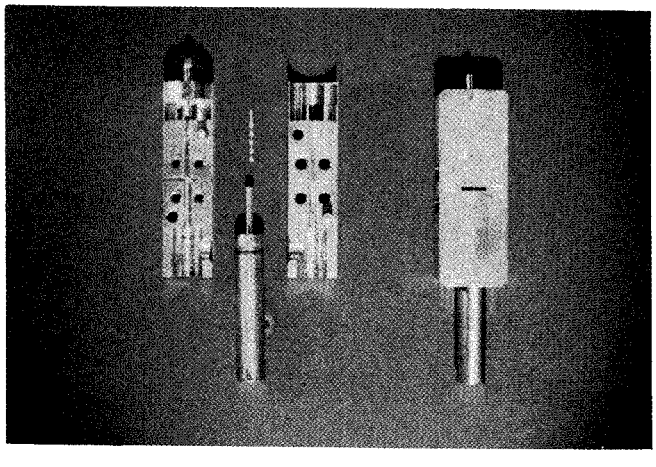

Figure 1 Single parts of the wafer and assembled unit

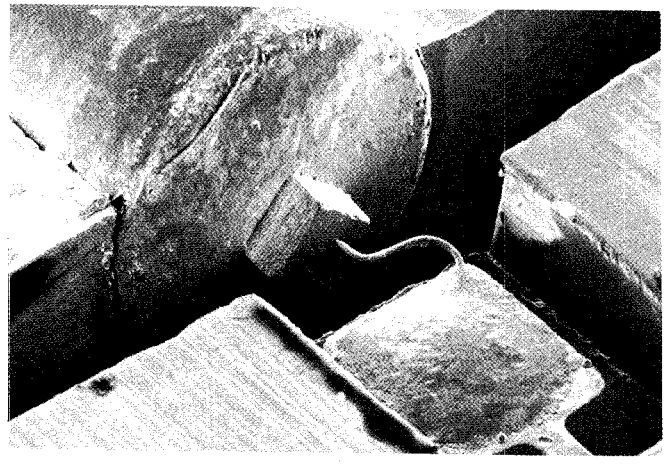

Figure 2 Whisker-contacted Schottky-barrier mixer diode

The wafermount consists of a waveguide transformer, a reduced hight waveguide section to hold the backshort and a plate with a coaxial plug to contact the IF-port of the filter. The wafer is inserted into the wafermount and fixed by the shortplate. Figure 3 shows wafer and wafermount separately and mounted into on another.

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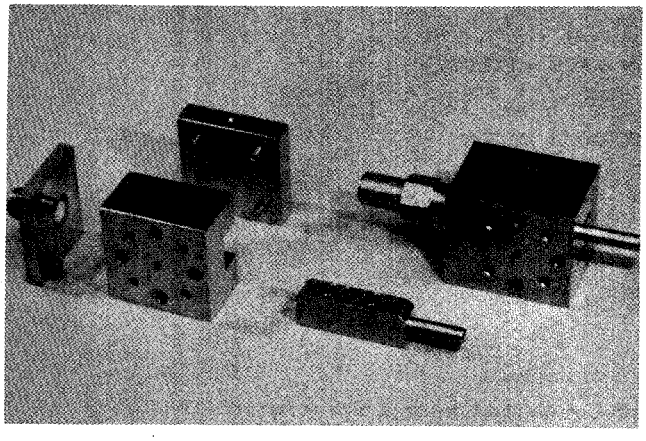

Figure 3 Single parts of the mixer and assembled unit

Diode

The diodes were fabricated at "Millimetre Wave Technology" in Cork, Ireland. The diode characteristics are summerized in Table I. The measured values result in a cut off frequency of about 4450 GHz. These diodes are near-ideal as presented in [4] and are suitable up to 300 GHz.

Epilayer thickness	: 0,125 µm
Epilayer doping	: 2×10^{17} cm^{-3}
Substrate doping	: 2×10^{18} cm^{-3}
Diode diameter	: 2 µm
Series resistance (dc)	: 7,3 Ω
Junction capacitance (0V)	: 4,9 fF
Break down voltage (1 µA)	: 6 V

Table I Diode characteristics

Measurements of the variation in diode capacitance with applied voltage resulted in very small values: 0,5 fF from 0V to -3V typically. Keen[5] and others[6] showed that these diodes, called "Mott diode", are very suitable for low noise millimeter wave mixers since less shot noise is obtained. A second benefit is the low local oscillator power these diodes require. The best mixer noise temperatures can be achieved with powers of 200 µW to 400 µW.

Measurements

Narrowband Mixerdesign

The mixer was designed for the frequency range of 75 GHz to 110 GHz. The intermediate frequency is 500 MHz ± 100 MHz. Measurements of single side band noise temperature and conversion loss versus local oscillator power are shown in Figure 4. A relatively flat region can be seen in the power-range between -2 dBm to -10 dBm. The best SSB noise temperature of 600°K has been obtained at 250 µW. The conversion loss is about 5,7 dB at this power level.

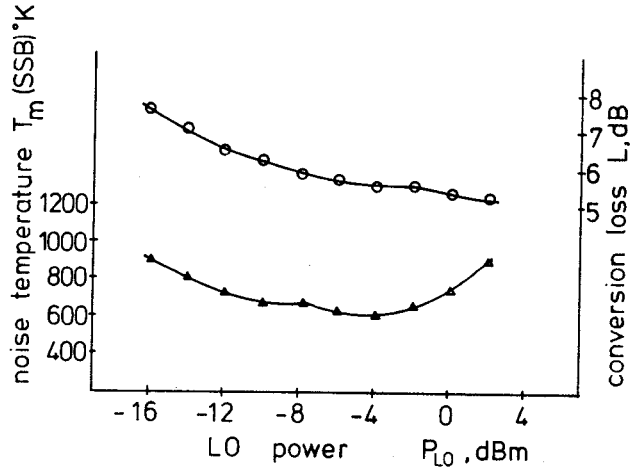

Figure 4 Mixer noise temperature (SSB) as a function of local oscillator power (f_{LO} = 94 GHz)

The measurements were carried out with different L.O.-sources at 94 GHz. Due to the low power requirements it is possible to use low power fundamental Gunn-oscillators as well as cavity stabilized Gunn-doublers. No L.O.-filter has been used to supress the local oscillator noise sidebands. The measurements have not been corrected for contributions from any mismatch.

Mixerdesign for an IF from 3,7 GHz to 4,2 GHz

The mixerdesign is the same as described in the previous section, complemented by an IF-matching circuit for 3,7 GHz to 4,2 GHz and a bias-tee. Figure 5 shows conversion loss and SSB noise temperature as a function of intermediate frequency. As the mixer is a double sideband mixer the values shown have been calculated from the measured DSB noise temperatures. At an L.O. power of 500 µW the SSB noise temperature is between 600°K to 800°K in the IF region between 3,7 GHZ and 4,2 GHz.

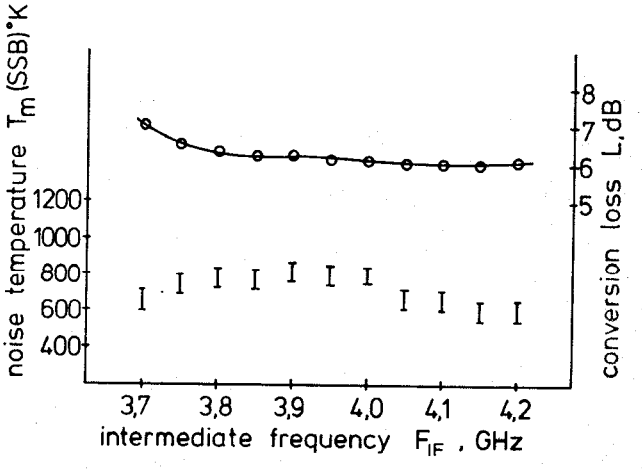

Figure 5 Mixer noise temperature (SSB) and conversion loss as a function of intermediate frequency (f_{LO} = 90 GHz)

Wideband Mixerdesign

A mixer has been designed which shows that a mixer with whisker-contacted diodes is very broadband. The design is the same as described before. A specially designed bias tee is used for the intermediate frequency from 1 GHz to 18 GHz. With a fixed short position and constant bias the conversion loss is 7 dB ± 1,5 dB in the IF range 1 to 15 GHz. So it is possible to convert the complete band from 75 GHz to 110 GHz with a local oscillator fixed at 90 GHz. Figure 6 shows the measured conversion loss in the frequency range from 75 GHz to 90 GHz. The values for the upper sideband correspond to these data. To obtain the conversion loss mentioned above, an L.O. power of -5 dBm is required.

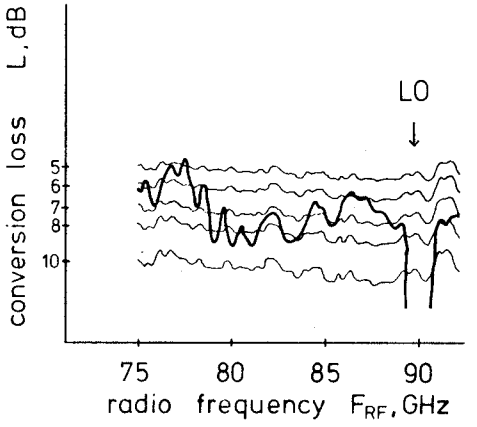

Figure 6 Mixer conversion loss as a function of radio frequency (f_{LO}= 90 GHz)

The mixer design is very suitable for broadband surveillance radar and mm-wave spectrum analyzer applications.

Mixers designed for the frequencyband from 110 GHz to 170 GHz have also been built up and tested. Data of these mixers will be presented.

Environmental tests

Shock and vibration tests have been carried out in order to prove that whisker-contacted Schottky diode mixers are, mechanically speaking,rugged devices. Seven mixermounts have been tested simultaneously, each with an applied bias voltage. The voltage drop across the diode has been recorded with a fast luminous point recorder to registrate interruptions and total drop outs. The test conditions are given in Table II. These results show that all tested mixers met Mil specifications STD-810 C for equipment installed in ground launched missiles. At a considerably higher value of 1200 g/2 ms only one of the mixers failed. During the following vibration tests - sinusoidal and random - none of the mixers broke down.

	peak value/g's	nom.duration/ms	failure
Shock parameters	100	6	- acc. MIL-STD-810C
	150	4,5	-
	200	4	-
	300	4	-
	500	2	-
	700	2	-
	900	1,5	-
	1200	2	1

	frequency/Hz	cycling time/min	max.accel./g's
sinusoidal vibration	10 - 2000	30	10
	100 - 2000	5	40
random vibration	50 - 2000	30	9,3 (RMS)

Table II Environmentmental test condition

Conclusion

This paper shows that high reliability can be combined with low noise and low local oscillator power requirements using whisker contacted Schottky diodes to build up mm-wave mixers. Single sideband noise temperatures of 600°K at an L.O.-power of 250 µW have been obtained. Wideband-mixers with an IF-bandwidth of 15 GHz can be realized with the same mixer design.

Acknowledgements

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