AN UNUSUAL MICROWAVE MIXER

G. Tomassetti[*]

ABSTRACT

Some preliminary measurements on an unusual microwave mixer configuration are reported. The mixer employied a single gate, packaged GaAs FET in a novel coaxial mount. The L.O. power and the I.F. were fed to and taken from the drain while the input R.F. signal was connected to the gate. A conversion gain of 2 dB and 270K DSB "mixer" noise temperature were measured at X band. Cooling the unit to 60K, a "mixer" noise temperature of 80K was obtained across a 10% bandwidth. At K band a 3 dB conversion loss and 880K DSB noise temperature were measured. The latter figure dropped to 180K at cryogenic temperatures.

INTRODUCTION

In radioastronomy and space applications cryogenic front ends are commonly and successfully used. However, high gain low noise front ends are neither easy to design, nor to make, especially above the 20 GHz mark.

Complexity and costs would be reduced if the front end could be followed by a really low noise mixer.

This paper discusses the design and implementation of such a mixer. In practice two units were built for X and K bands. Most of the measured data were taken on the X band unit because it was easier and our instrumentation more complete, but fundamental parameters like noise temperature and conversion loss were measured also on the K band unit.

These mixer should still be considered "experimental" because tests will continue in the future when HEMT devices become available.

DESCRIPTION

In our laboratory cryogenic coaxial microwave amplifiers are commonly built according to a well accepted design [1][2][3].

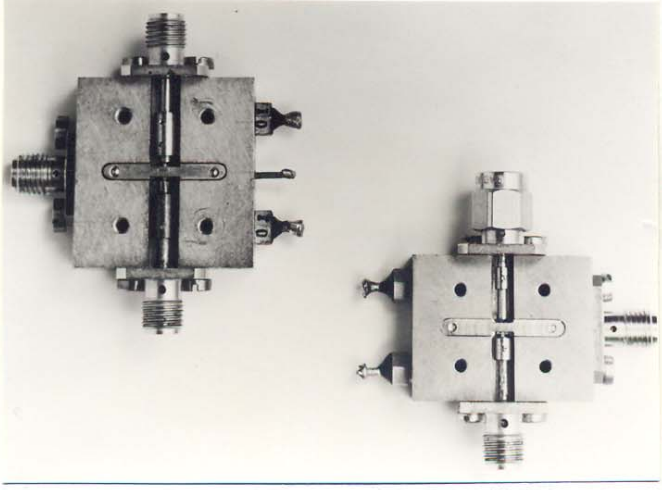

Fig. 1: A photo of the X and K band mixers.

It was recently realised that a GaAs FET, single gate, coolable mixer could be implemented by using one of these amplifiers, and the electrical and mechanical modifications to turn it into a mixer were of minor relevance.

The basic idea was to make a 3 port mixer by applying the R.F. input signal to the gate and the L.O. to the drain thus fully retaining the existing matching networks. The I.F. voltage was available across a load resistor connected after the low-pass filter biasing network of the drain. See Fig. 2 for electrical details.

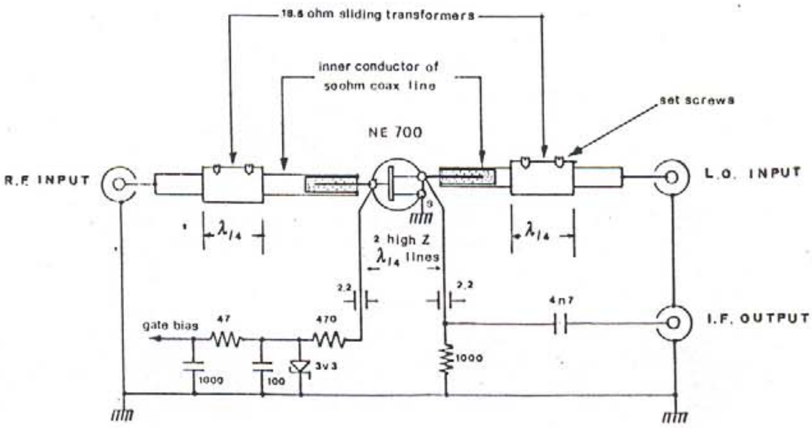

Fig. 2: Wiring diagram of the microwave mixer.

In order to choose a suitable working point, the static direct and reverse d.c. drain characteristics were measured and plotted with the gate voltage as a parameter. It was observed (see Fig. 3) that curves relative to gate voltages Vg = −.6 and Vg = −.7 Volt were approximate almost perfectly by a parabola in the range of drain voltages $V_D = \pm .4$ Volt, consequently producing a very favourable locus for efficient mixing. In addition, as this locus is symmetric with respect to ground, drain d.c. biasing need not be applied. Only 4 or 5 mW of L.O. power will produce the drain voltage swing (±.4 Volt) necessary for a correct operation.

Negative gate bias, however, remains essential as it effects heavily the mixer noise temperature, tuning and bandwidth, as shown in Fig. 4.

The input matching networks were computed by standard Smith chart procedures using the "low noise" set of S parameters found in the literature and were made according to the original design [1]. The two visible slugs (see the photo of Fig. 1) are λ/4 long and can slide over the 50 ohm main transmission line in order to be set at the proper distance from the FET which is mechanically held in position by the central strap. The characteristic impedance of the slugs changes the absolute value of the reflection coefficient, and the distance changes the phase. With this arrangement any impedance transformation is, in principle, made possible. The biasing of the FET is obtained by λ/4 wires from the chip capacitors housed in the bottom of the box. The input d.c. blocking capacitors are formed by inserting the FET leads into the tips of the 50 ohm lines which had been previously drilled and teflon lined. This solution offers distinct advantages i.e.:

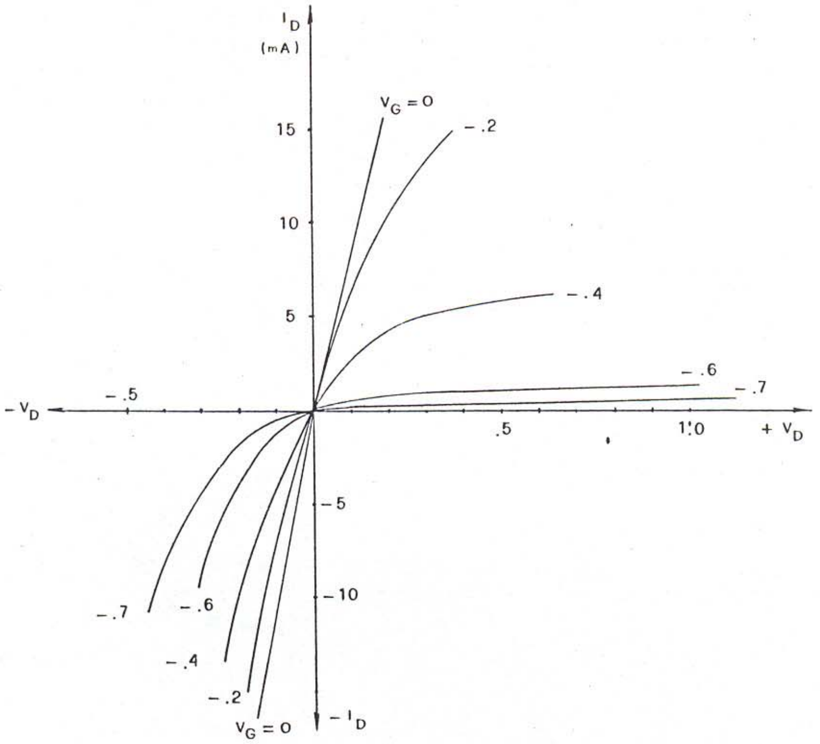

Fig. 3: Static direct and reverse d.c. drain characteristics of a common GaAs FET with gate voltages as parameter.

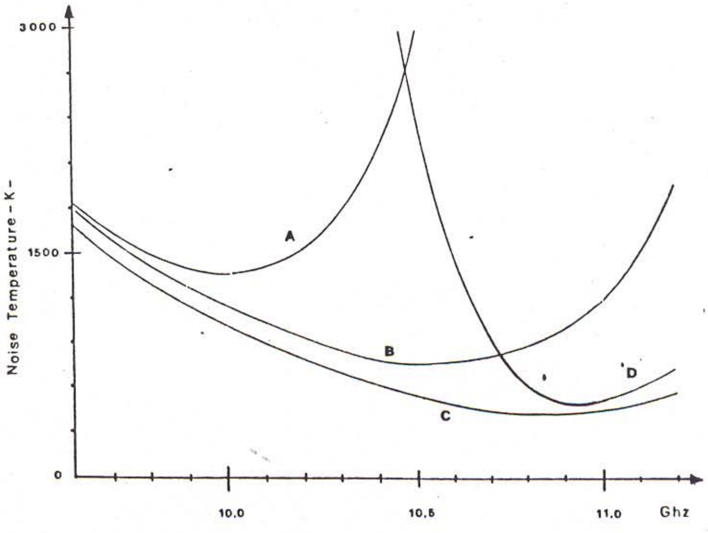

Fig. 4: Noise temperature vs. frequency of X band mixer in the range of gate voltages -.4 (A) to -1.0 Volt (D).

i - as the FET sees it as a series low impedance line, its length can be varied to realise an easier matching;

ii - as there are no connections soldered to the FET, the entire matching section can be easily pulled out for any physical substitution of the slugs.

The I.F. output voltage is available across a 1000 ohm resistor in series with the low pass drain biasing network. I.F. frequencies from 30 to 2000 MHz were successfully used with little or no deterioration in performance. The simple I.F. output network shown in Fig. 2 gives about 10 dB return loss at 30 MHz and about 5 at 2 GHz. Improved values can of course be obtained on narrower bandwidths by more complex designs.

RESULTS

A summary of the most important measurements taken on the two units is now given both at room and cryogenic temperatures.

X BAND MIXER

The conversion loss is a function of the L.O. power and gate bias applied to the circuit (see Fig. 5 and Fig. 6). At +10 dBm a gain of about 2 dB was obtained. Zero dB loss was measured at +6 dBm. At the latter L.O. power level a minimum DSB "mixer" noise temperature of 270K was attained using a cheap NE700 GaAs FET at room temperature. Cooling the unit to 60K, it was observed that conversion loss remained unchanged but DSB "mixer" noise temperature had dropped to about 80K. No improvement was measured by further reducing the physical temperature. Gate biasing, however, had to be set some 10% more negative for best results.

The saturation was next measured at +6 dBm L.O. level. The 1 dB compression point was reached at -7 dBm R.F. input power.

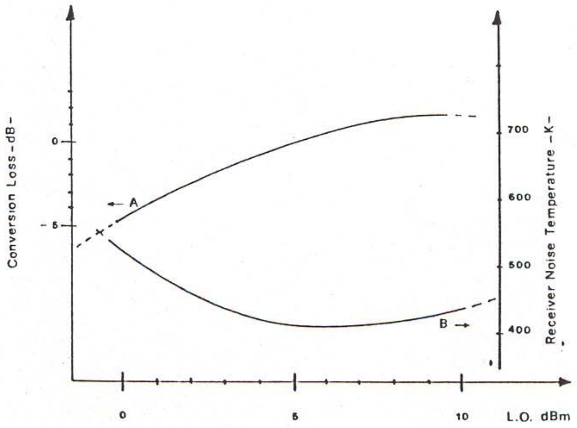

Fig. 5: Conversion loss (A) and noise temperature (B) vs. L.O. power of X band mixer.

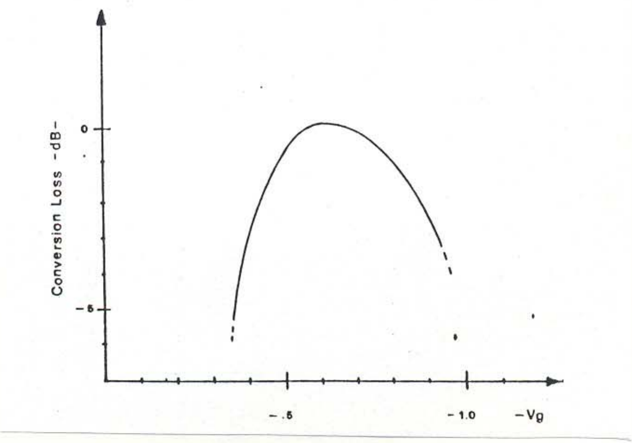

Fig. 6: The effect of gate biasing on conversion loss.

The isolation between any two ports was then measured as follows:

L.O. to R.F. = 13 dB
L.O. to I.F. = 30 dB
R.F. to I.F. = 38 dB
R.F. to L.O. = 7 dB (I.F. = 30 MHz); 14 dB (I.F. = 1 GHz).

K BAND MIXER

The photo of Fig. 1 shows that the X and K band mixers look very much alike. In fact the K band mixer is a scaled down version of the X band unit, the only differences being physical dimensions and FET used. At 22.5 GHz an NE673 .3 μm gate length was employied.

One of these packaged devices gave the following results:

conversion loss ≃ 3 dB at +6 dBm L.O. power
"mixer" DSB noise temperature at 300K ≃ 880K
"mixer" DSB noise temperature at 60K ≃ 180K

These noise temperature were attained at the design frequency but "usable" values were measured from 19 to 25 GHz.

CONCLUSIONS

A new, highly efficient mixer configuration is presented. It is shown that single gate, packaged devices can be used up to 25 GHz. Conversion gain can be realised given the proper conditions. Cooled to cryogenic temperatures the mixers show very low noise temperatures, even at K band.

It is expected that the implementation of this design will contribute to reducing the complexity and cost of radioastronomy and space cryogenic receivers.

The K band unit just described has been successfully used during the May 1986 VLBI European Run at 22.20 GHz at the Bologna Radioastronomy Station.

REFERENCES

(1) Tomassetti, G.; Weinreb, S. and Wellington, W.: "Low noise, 10.7 GHz, cooled GASFET Amplifier", Electronic Letters, 17, no 25/26, 1981.

(2) Sierra, M.: "15 GHz cooled GaAs FET Amplifier. Design background information", N.R.A.O. E.D.I.R., no 229, June 1982.

(3) Pospieszalki, M.: "Low noise, 8.0 - 8.8 GHz, cooled GASFET Amplifier", N.R.A.O. E.D.I.R., no 254, Dec. 1984.

ACKNOWLEDGEMENTS

Dr S. Weinreb of N.R.A.O., Charlottesville (U.S.A.) and Prof. G. Sinigaglia of the Bologna University are acknowledged for valuable discussions and suggestions.