Radio Interferometry: Theory, Techniques and Applications, IAU Coll. 131, ASP Conference Series, Vol. 19, 1991, T.J. Cornwell and R.A. Perley (eds.)

CRYOGENICALLY-COOLED, HEMT AMPLIFIERS AND RECEIVERS IN 1-50 GHZ RANGE: STATE-OF-THE-ART

MARIAN W. POSPIESZALSKI
National Radio Astronomy Observatory*
2015 Ivy Road, Charlottesville, Virginia 22903

ABSTRACT A review of the recent developments in the design, construction and performance of cryogenically-coolable, high-electron-mobility transistor (HEMT, MODFET) amplifiers and their application in compact cryogenic receivers for radio astronomy applications is presented.

INTRODUCTION

A simple wideband model introduced in recent papers (Pospieszalski, 1988, 1989) allows for the design of cryogenic amplifiers with optimized noise performance over a given frequency bandwidth (Pospieszalski, *et al.*, 1990). As a result, the realization of the low-noise radio astronomy receivers having "optimal," within other design constraints, noise bandwidth performance becomes possible.

This paper presents first a review of the performance of a family of cryogenically-coolable amplifiers developed at the NRAO Central Development Laboratory in the 1 to 50 GHz range and then a review of the performance of receivers employing these amplifiers.

Finally, several observations are offered concerning the current state and future trends in the development of cryogenically-coolable HEMT (MODFET) receivers.

CRYOGENIC AMPLIFIERS

A summary of the typical performance of cryogenic HEMT amplifiers is presented in Fig. 1. The noise temperature data are referred to the cold input of the amplifier. The noise performance of these amplifiers is plotted against the minimum

*The National Radio Astronomy Observatory is operated by Associated Universities, Inc. under cooperative agreement with the National Science Foundation.

noise measure of the FHR02X HEMT (Pospieszalski, *et al.*, 1990), a quarter-micron gate device available from Fujitsu. Also, the noise temperature of the 38-45 GHz amplifier is plotted against the minimum noise measure of the .1 μm gate HEMT device from Linear Monolithics (Weinreb, *et al.*, 1989). The data for the 4 K masers (Petty, 1983; Shell, 1988) are given for comparison. The amplifier examples demonstrate that for the bandwidth of around an octave or less the amplifier average noise temperature is equal to the minimum noise measure at the highest frequency within the band.

RECEIVERS

The general concept of a compact, low-noise, HEMT receiver for radio applications has been outlined by Weinreb, *et al.* (1988) and several examples are given therein. The examples of performance of wideband designs are shown in Figs. 2 and 3 for K_u- and Q-band, respectively. The K_u-band results are for the VLBA receiver in which the narrow band low-noise amplifier was replaced with the new 12-18 GHz design. It is clearly seen that the receiver performance is limited, both in terms of noise and bandwidth, by the components placed ahead of the amplifier. In this particular case, the noise degradation is due to the cumulative losses of polarizer, coupler, isolator and connecting cables while the bandwidth is limited by the polarizer only. The performance of the Q-band receiver is for a laboratory version and includes the contributions of a feed horn and dewar transition. In particular, the bandwidth of the Q-band receiver is limited by the "gapped" waveguide dewar transition.

CONCLUSIONS

The trade-off in low-noise amplifier design (bandwidth, input VSWR, stability, gain) can be reliably investigated in a computer model leading to the design with "optimal" noise bandwidth performance. The bandwidth of a receiver is no longer limited by the amplifier bandwidth. Also, at lower microwave frequencies, only a small fraction of the system noise is contributed by a HEMT amplifier. The Q-band experimental HEMT receiver demonstrates the performance competitive with that of SIS/HEMT IF receivers. It is expected that wide bandwidth HEMT receivers will compete with SIS/HEMT IF receivers at 100 GHz.

REFERENCES

Petty, S. M. and D. L. Trowbridge, "Low-Noise Amplifiers," in *Deep Space Network - Radio Communications Instrument for Deep Space Exploration*, JPL Publication

82-104, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, July 1983.

Pospieszalski, M. W., "A New Approach to Modeling of Noise Parameters of FET's and MODFET's and Their Frequency and Temperature Dependence," National Radio Astronomy Observatory Electronics Division Internal Report No. 279, Charlottesville, VA, July 1988.

Pospieszalski, M. W., J. D. Gallego, and W. J. Lakatosh, "Broadband, Low-Noise, Cryogenically-Coolable Amplifiers in 1 to 40 GHz Range," in *Proc. 1990 MTT-S Internat'l. Microwave Symp.*, pp. 1253-1256, Dallas, TX, May 1990.

Pospieszalski, M. W., "Modeling of Noise Parameters of MESFET's and MODFET's and Their Frequency and Temperature Dependence," *IEEE Trans. on Microwave Theory and Tech.*, vol. MTT-37, pp. 1340-1350, Sept. 1989.

Shell, J. and D. Neff, "A 32 GHz Reflected-Wave Maser Amplifier with Wide Instantaneous Bandwidth," in *Proc. 1988 IEEE MTT-S Internat'l. Microwave Symp.*, pp. 789-792, New York, NY, June 1988.

Weinreb, S., M. W. Pospieszalski, and R. Norrod, "Cryogenic, HEMT, Low-Noise Receivers for 1.3 to 43 GHz Range," *Proc. 1988 IEEE MTT-S International Microwave Symp.*, pp. 945-948, New York, NY, May 1988.

Weinreb, S., R. Harris and M. Rothman, "Millimeter-Wave Noise Parameters of High Performance HEMT's at 300 K and 17 K," in *Proc. 1989 IEEE MTT-S Internat'l. Microwave Symp.*, pp. 813-816, Long Beach, CA, June 1989.

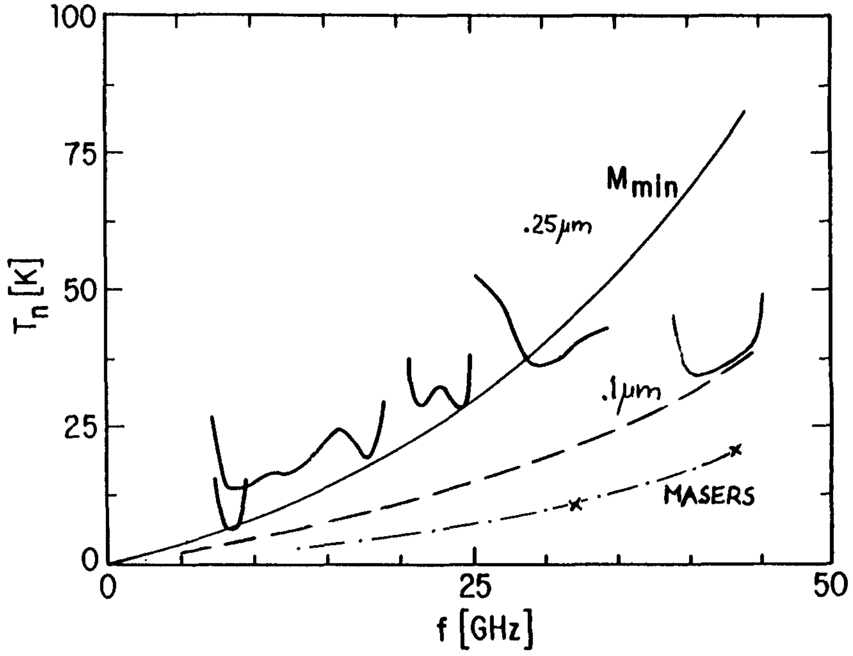

Fig. 1. Noise temperature of different amplifiers and minimum noise measure of FHR02X (.25 μm gate length) and H-CF-100-6 (.1 μm gate length) at T_a = 12.5 K. The noise performance of masers at 4 K is also shown for comparison.

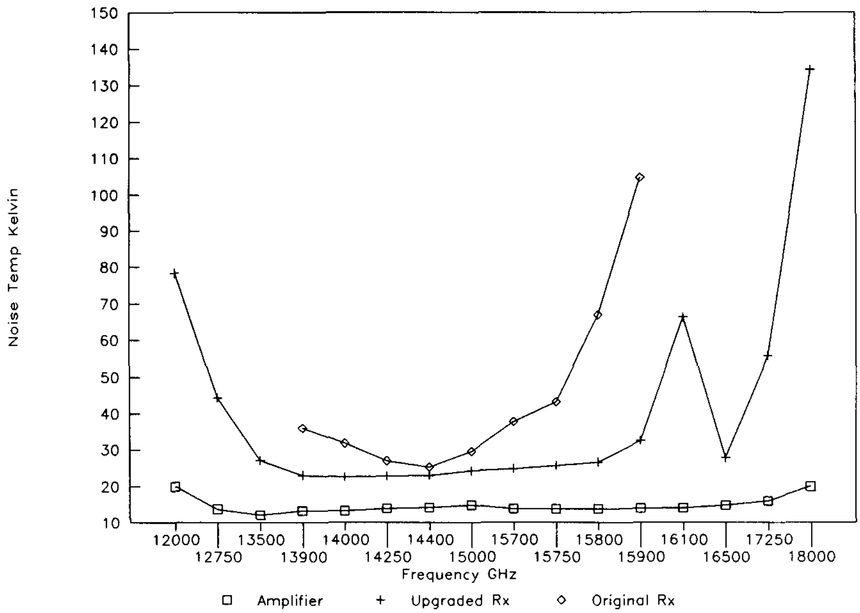

Fig. 2. Noise performance of cryogenic K_u-band amplifier and receiver. The noise performance of the same receiver with the narrow band amplifier is also shown.

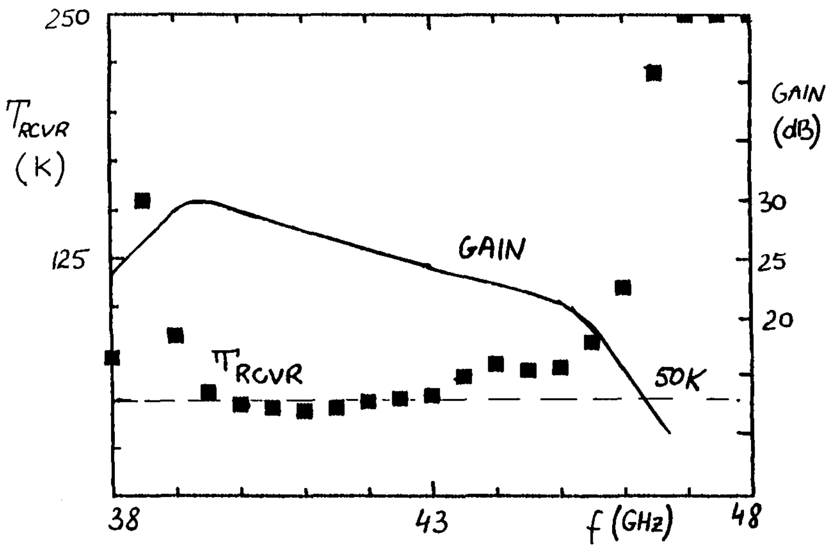

Fig. 3. Noise performance of the laboratory version of the Q-band receiver. Gain of the cryogenic amplifier is also plotted.

https://doi.org/10.1017/S0252921100013063 Published online by Cambridge University Press

David Woody: Have we reached the limit to the noise temperature of HEMT Amplifiers?
Marion Pospieszalski: Not yet. I would expect all HEMT receivers to be competitive with SIS/HEMT IF receivers up to 100 GHz with presently available planar HEMT technology.

Peter Hall: What devices are you using in the Q-band (43 GHz) receivers?
M. Pospieszalski: The HEMTs in question are linear monolithics (now ROHM Research Co. 31225 La Baya Drive Westlake Village, CA 91361, Dr. Robert Lee, Ph. 818-991-7000) .1μm x 100μm devices.

Goran Pilbratt: If you would look five years into the future, for how high a frequency would you expect an all-HEMT receiver to be competitive?
Marion Pospieszalski: I would expect all HEMT receivers to be competitive with SIS/HEMT if receivers up to 100 (or 115?) GHz with the presently available planar HEMT technology. This will probably be demonstrated within one to two years' time. Current device concepts are not likely to produce receivers with competitive noise performance above 140 GHz. I believe that a novel device would be needed to break this frequency barrier.

https://doi.org/10.1017/S0252921100013063 Published online by Cambridge University Press