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LOW-NOISE TECHNOLOGY, 1982 STATE-OF-THE-ART

(Invited Paper)

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Abstract

The current noise performance in the 100 MHz to 300 GHz range of transistors, paramps, masers, Schottky diode mixers, and superconductor-insulator-superconductor (SIS) mixers will be summarized and compared with the natural limits due to cosmic noise, atmosphere, and quantum effects. Recent advances concerning cooled FET amplifiers, cryogenic coolers, and millimeter wave mixers will be discussed.

Introduction

The current state-of-the-art of low-noise microwave devices is summarized in Figure 1 which is based upon the references categorized below and also upon measurements of systems in use at National Radio Astronomy Observatory facilities. In all cases, it is the receiver noise temperature that is plotted; noise contributions from transmission lines and the antenna are neglected and mixer values are single-sideband receiver noise temperatures assuming a state-of-the-art I.F. amplifier.

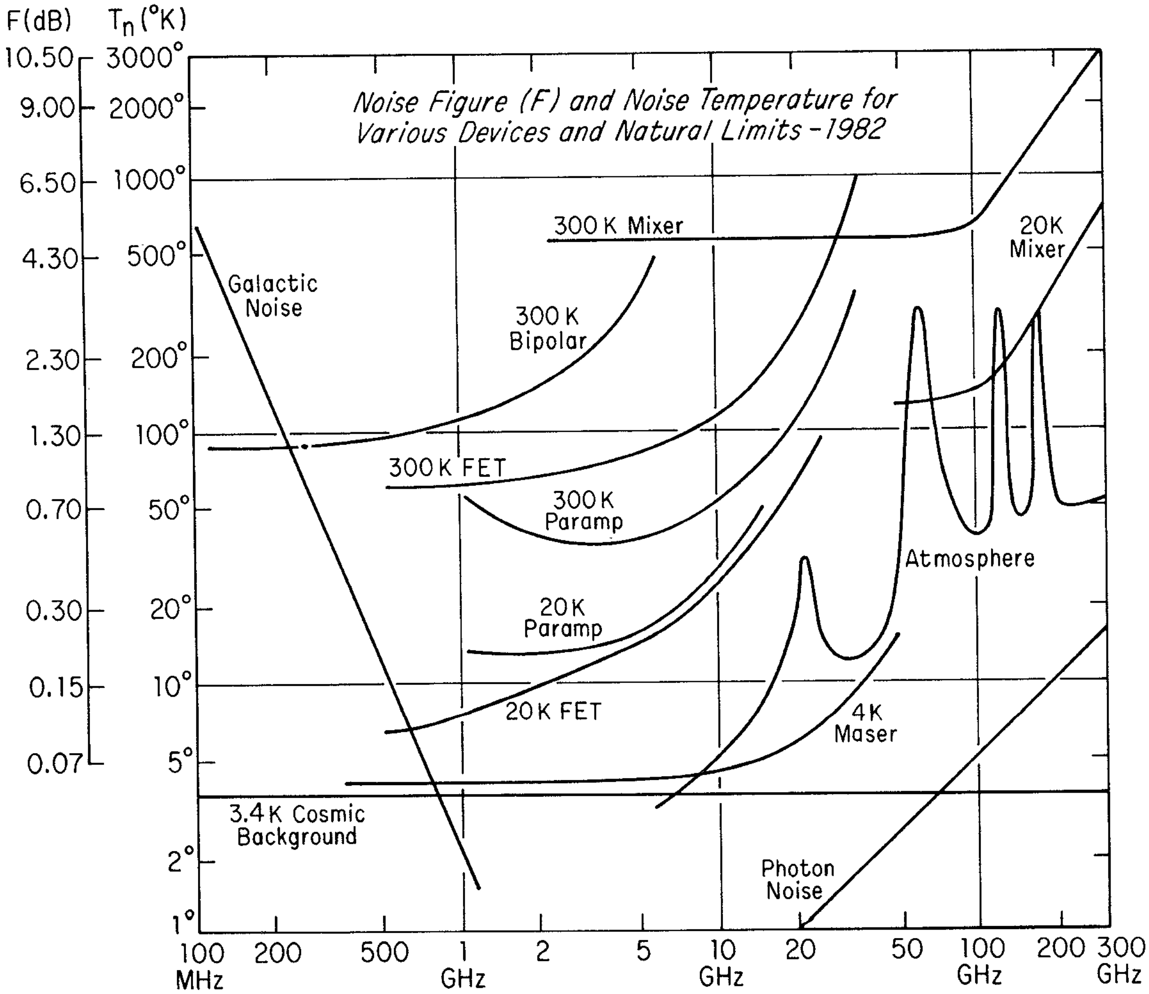

Fig. 1. Noise performance of 1982 state-of-the-art, low-noise microwave devices compared with naturally occurring contributions to system noise.

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The natural limits to radio communication are galactic noise in the 100 MHz to 1 GHz range, the 3.0K cosmic background in the 1 GHz to 10 GHz range, and, for earth-based systems, atmospheric noise in the 10 GHz to 300 GHz range. For receivers in space above 10 GHz and with antennas not receiving radiation from a hot object such as the earth, the noise limit is the cosmic background and, above 100 GHz, photon noise due to quantization of energy.

It is a challenge to the microwave engineer to reduce receiver noise below these natural limits. At frequencies below 300 MHz this has been forever accomplished with small, efficient, and inexpensive transistor amplifiers. In the 1 to 30 GHz range, the noise limit can only be reached with expensive masers requiring 4K cooling. For earth-based systems, the leakage of 300K earth radiation due to rain, antenna spillover, or sidelobes often adds 5K to 50K to the system noise and an ultra low-noise receiver is wasted unless it can be accompanied by a well-selected location and antenna design.

During the past several years, the GaAsFET amplifier has given the microwave engineer a wonderful new building block with an order of magnitude less noise than TWT's, TDA's, or mixers. However, natural noise limits are still not reached with room temperature GaAsFET's. A factor of 3 to 10 improvement in noise temperature would allow smaller antennas, enhance system performance, and generally increase the viability of many microwave systems. The attainment of this improvement, which will probably require either a radical change in the FET structure or a departure from GaAs, should be a major goal of microwave device development in the 1980's.

At present, a factor of 5 improvement of the noise of a GaAsFET amplifier, can be obtained by cooling to 20K[8-10]. This can be accomplished with refrigeration equipment weighing less than 45 kg and costing approximately $5,000. A miniature, no-moving part, gas expansion refrigerator has recently become available[24]. (Examples of amplifiers and refrigeration equipment will be shown in slides at the conference.)

Considerable progress has been made in the low-noise millimeter-wave field during the past 10 years. Room temperature Schottky-diode mixers giving receiver noise temperatures of 588K (F = 4.8 dB) at 115 GHz and 1300K (F = 7.4 dB) at 230 GHz have been reported[11,12]; these same mixers give noise temperatures of 124K and 500K, respectively, when cooled to 20K. An exciting new cryogenic mixing device, the SIS junction, has achieved a mixer noise contribution of 9 $\pm$ 6K with 4 dB conversion gain in a laboratory experiment at 36 GHz[14]. (Further information regarding millimeter mixer developments will be presented at the conference.)

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