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PELTIER-COOLED MICROWAVE GASFET LOW-NOISE AMPLIFIER AND ITS APPLICATION FOR THE RATAN-600 RADIOMETERS*

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ABSTRACT. *GASFET low-noise amplifier with Peltier cooler for the first stage is described and its application to radio-astronomy receivers front-ends is briefly discussed. Specimen parameters realized are: for* $\lambda = 6.2$ *cm and* $\Delta f = 500$ *MHz* $T_N = 60\text{-}65$ *K, for* $\lambda = 8.2$ *cm and* $\Delta f = 500$ *MHz* $T_N = 55\text{-}60$ *K with 30 dB gain in both cases. The RATAN-600 radiometer with 8.2 cm amplifier as a front-end has 7* $mK/s^{1/2}$ *sensitivity.*

A microwave receiver front-end based on GASFET amplifier is designed as a universal unit, suitable for satellite communication, radiometry and radioastronomy applications. The main design goals were the lowest possible noise temperature and high reliability.

Currently, GASFET with Shottky-barrier gate amplifier has to some extent a higher noise temperature comparing with PARAMPs, but surpasses PARAMPs in size, weight, energy consumption, shock resistance and cost.

For the unit under discussion we use transistors with $T_N \simeq 60$ K at 3.5 GHz. Having such transistors, one can not make an amplifier with $T_N \leqslant 60$ K without transistor cooling. Thermal noise of current carriers in FET channel, which are most significant at room temperature, falls down with cooling. At the same time, input and

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output FET impedances change insignificantly. Thus, the GASFET amplifier, designed for room temperature conditions, can work satisfactory when cooled; some detuning can be compensated by gate bias change. This feature makes tuning simple and reduces specifications for cooling temperature stability.

As can be seen in Fig. 1, FET noise parameters are non-linearily dependent on cooling temperature: it is some kind of saturation in cryogenic temperatures range (Fig. 2). Noise temperature decreases rapidly at physical temperature range from +60 to -50° C. Theoretical estimation using (RCA Rev., 1981) shows significant improvement of FET parameters, when cooled down to -50° C. Peltier microcooler for local cooling of the first stage of the amplifier will be the most economical choice for the temperature range mentioned above (author's certificate, 1982).

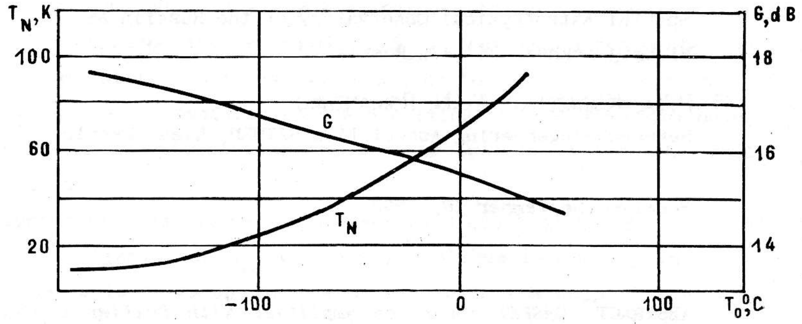

Fig. 1. *Noise temperature T_N and gain G vs crystal physical temperature T_0.*

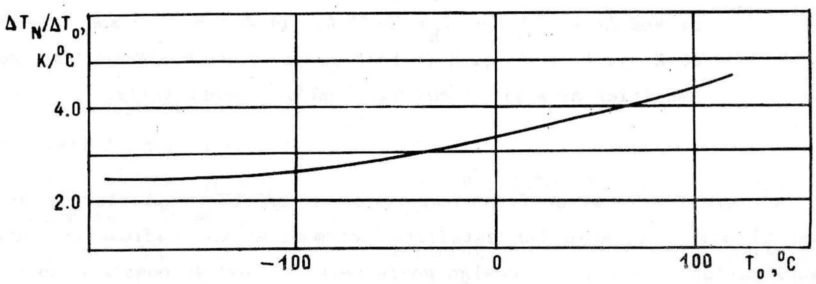

Fig. 2. *$\Delta T_N/\Delta T_0$ vs T_0 for FET specimen.*

The next design step must be the choice and calculations of input and output matching cirquits between this particular FET and standard feedlines. The problem to solve is to maximize a power transfer from a signal source to the amplifier output via FET within the definite bandwidth and at minimum noise figure. These conditions will be fulfilled if a matching cirquits impedance will be complex conjugated in comparison to input and output FET impedance. Dissipative losses in matching cirquits must be minimum because of their direct influence on the amplifier noise parameters.

One can use high-Q resonators as matching cirquits (theory can be found in (Matthaei et al., 1971), and form a frequency responce of the amplifier exactly coinciding with the informative signal frequency band, thus filtering out undesired interferencies without installing a separate filter unit and not adding losses and deteriorating the noise quality.

Taking this into account, it is very attractive to make use waveguide-below-cutoff (WGBC) resonators as matching cirquits. A waveguide section represents (Kirillov and Dvoskina, 1974) an inductive impedance when excited at frequency below cutoff. Adding to such a waveguide a capacitive-impedance element, one can obtain a high-Q resonating matching cirquit with easily adjustable transformation factor.

WGBC resonators are much smaller (5-10 times) in volume in comparison with waveguide resonators for the same frequency, but are inferior to some extent in electric characteristics. Then, a WGBC resonator has small distributed capacitance and high resonant impedance, which makes active element connection to the capacitive gap easy.

One more advantage of the WGBC resonator is that there is no possibility for parasitic oscillations propagation down to the λ_c. It means, that if we have out-of-band signals at the input of the device, these signals will attenuate exponentially. This feature of the amplifier cirquit increases selectivity of the device and prevents it from being blocked by powerful out-of-band signal.

Summing up, the main principles of the microwave amplifier design under consideration are:

- use of GASFET Schottky-barrier gate transistors as basic active elements;
- matching cirquits are based on high-Q WGBC resonators;
- local cooling of the first transistor down to -50°C with Peltier microcooler is used to ensure noise temperature under 60-70 K.

The design of the amplifier is based on a set of WGBC resonators with adjusting capacitive screws. To assure stability of each stage and to prevent feedback there is an iris with a window-mounted transistor between input and output matching resonators.

There is no adjustment coincidence for VSWR minimum and T_N minimum for common source FET stage, matched for T_N minimum. Input VSWR for such a stage may be as high as 4-8. There is strong need to use input ferrite isolator to realize normal input VSWR of the device and to prevent signal source impedance influence on the amplifier characteristics. The coaxial ferrite isolator was used for this design.

The structural layout of the design is as follows. There is a post-type waveguide-to-coaxial adapter at the input of the device. The post of the adapter is ohmically connected to the input ferrite isolator, the latter is connected to the amplifier WGBC resonator stage by loop exciter. There is one more screw at the resonator to compensate loop-induced reactance. Next follows the active element (FET) and the output WGBC resonator above mentioned. The second amplifier stage, if necessary, can be connected to the output waveguide-to-coaxial adapter (similar to the input one). The design sketch is shown in Fig. 3, and the assembled amplifier photo in Fig. 4.

Several amplifier versions, based on the design described, have been investigated carefully. The noise temperatures realised were 50-55 K, 55-60 K and 60-65 K for the frequency bands 3.65-3.90 GHz; 3.40-3.90 GHz and 4.55-5.05 GHz, respectively, with gain varied from 13 to 30 dB.

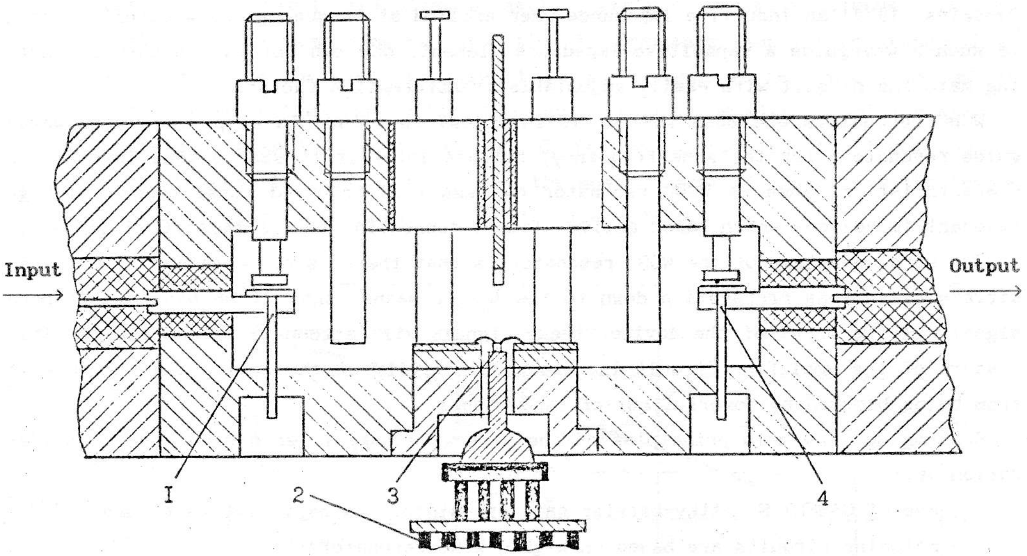

Fig. 3. *FET amplifier design sketch: 1,4 - input and output transformers; 2 - Peltier cooler; 3 - FET.*

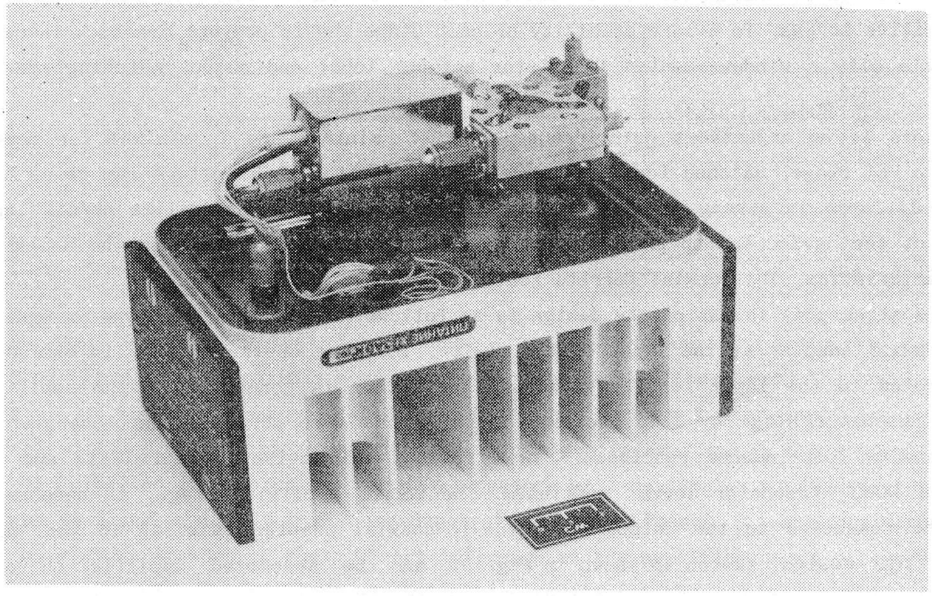

Fig. 4. *GASFET microwave amplifier photograph.*

The amplifier with 3.40-3.90 GHz bandwidth was used successfully as a front-end for the RATAN-600 radiometer, utilizing "periodical noise injection with synchronous gain switching" principle of operation (Berlin et al., 1982). The latter specifies a very high parameter stability, otherwise this type of the radiometer becomes unoperable. The application of the new FET amplifier gave the possibility to improve the radiometer reliability and to minimize size and weight (in comparison with the PARAMP front-end) with the result that 7 $mK/s^{1/2}$ sensitivity was realized.

An amplifier with 4.55-5.05 GHz bandwidth was chosen as a base for the multichannel front-end design for the linear phased array to be placed at the focal line of the RATAN-600 radiotelescope (Pinchuk et al., 1989). The first specimen of such a front-end consists of eight independent FET amplifier channels (placed in two thermostated enclosures, four amplifiers in each), later we are planning to have 32 channels. Peltier cooler for one enclosure needs 5 V, 10 A power supply. Let us remark in conclusion, that there is no real possibility to cool the 32-channel planar device by any other method except local Peltier cooler: for example, the use of a closed-cycle refrigerator seems physically and economically unrealistic.

REFERENCES

RCA Rev.: 1981, vol. 42, **4**, 661-671.

Author's certificate: 1982, HO3F 3/60 No. 1. 109877, 13.01.82.

Matthaei G.L., Young L., Jones E.M.T.: 1971, in: *Microwave filters, impedance-matching networks and coupling structures.* "Sviaz" Publ., Moscow.

Kirillov L.G., Dvoskina Yu.N.: 1974, *Zarubezhnaya radioelectronika*, No. 3.

Berlin A.B., Gassanov L.G., Gol'nev V.Ya., Korolkov D.V., Lebed V.I., Nizhelskij N.A., Spangenberg E.E., Timofeeva G.M., Jaremenko A.V.: 1982, *Radiotekhnika i electronika,* **27**, No. 7, 1268-1273.

Pinchuk G.A., Parijskij Yu.N., Shannikov D.V., Majorova E.K.: 1989, *Preprint SAO* USSR AS, No. 39.