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Super Low-Noisy Cooling Amplifier of Millimeter Range with Using the HEMT-Transistors

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Abstract. We have developed the construction and study cooling down to temperature $T_p = 18$ K transistors amplifier on the frequency of 22 GHz with bands transmission 10 - 15 %, having the amplification factor no less then 30 dB in the level of own noises 40 K in the range of 22 GHz and 50 K in the range of 36 GHz ($T_p = 18$ K).

1. Introduction. In the technics of super-low-noisy expedient of HTSC signals last time are actively introduced the amplifier devices on using the HEMT - transistors. Namely they provide maximum low meaning of equivalent noisy temperature of amplifiers of the frequency large band in the condition of depth cryogenics cooling (down to 18 K).

We have developed the construction of cooling down to temperature $T_p = 18$ K transistors amplifier on the frequency of 22 GHz and 36 GHz with bands transmission 10 - 15 %, having the amplification factor no less then 30 Db in the level of own noises 40 K in the range of 22 GHz and 50 K in the range of 36 GHz ($T_p = 18$ K).

2. Device preparation and microwave measurements. The construction of amplifiers are done by waveguide-planing, in which microcircuit TRA (transistor amplifier) had been installed in the waveguide of standard section in the E-surface perpendicular to the large waveguide wall. The TRA cascades are done separately with installation of the HEMT type of transistors on the cascade microcircuit. Properly for everyone they are merged in third and fourth cascade assembly with the sequence inclusion.

The most important achievement of the construction of TRA is monoconnection of the metal figure that creates combs of the inpute and output section of the fine-line that gives a possibility both to eliminate dielectric substrate from the construction and to make combs in the form of thick perforate plate-radiator (with the thickness of $t = 0,5$ mm). Playing filters of blocking, elements of fine tuning of the amplifier cascades and source filters are made directly on the plane surface of the above-mentioned plate by the group techniques of the thin films technology.

As the result input and output segments of the fine-line with fill in air have been obtained. On the plane surface of the combs of the fine-line microcircuit of the transistor amplifier has been formed. The selection of the thickness of combs and gaps between them allowed to obtain characteristic resistance of the inpute and output segments of N-image waveguide that is close to input and output resistance of the transistor. Such a resistance would simplify the solution of the problem of the wideband sequence of the transistor on input and output in the frequency range not less than 3 - 4 GHz.

The extension of the combs' thickness and the elimination of the dielectric substrate together with buffer film that provides adgejion of the dielectric with a metal film would give the possibility to decrease the losses in the matching segments of the N-waveguide. These losses are comparable with the losses in the ordinary waveguide and reach 0,003 - 0,05 dB, i. e. too small. The construction of the cascade of TRA with hybrid - integral microwave -circuit on the side surface of the comb of N-image waveguide is shown on the Fig. 1.

Figure 1: Construction of the TRA cascade with a hybrid-integral microwave microcircuit. 1 - body; 2 - contact wire; 3- source filters; 4 - transistor; 5 - wave-guide.

The cascade of TRA represents a segment of the rectangular waveguide of the standard cross-section with the length of 9 mm, inside of which the copper plate with a TRA microcircuit on one of the side surfaces is installed along its longitudinal axle perpendicular to the large waveguide wall. On the side surface is also assembled a transistor. In the copper plate fine line of the H - fine - line

of a certain configuration on the input and output of the transistor are formed by the electro-spark machining technique. As a rule, they are 3 steps matching transformers with the elements of compensating reactive crack (Fig. 2).

Figure 2: The variant of the TRA cascade topology.

The mechanics fine tuning of the cascades and amplifiers ordinary has been refused. Microcircuit of TRA is made on the side surface of the copper plate by the group techniques of the thin film technology. It includes source filters microwave block filters, the elements of fine tuning of the TRA (Fig. 2). Copper plates with the size of 24 x 30 x 0,5 mm obtained of sheet copper were used as a substrates.

After preliminary processing on the grinding bench mechanic lapping of the substrate surface has been executed by the diamond plates. During the finishing operation diamond powders with the granular of 1 - 0,5 micron have been used. As a result the surface with the cleanliness $R_z=0,04 - 0,032$ mkm has been obtained. Roughnesses are rubbed out on the "Photonika" laser interferometer.

Further these substrates were used for the construction of the TRA microcircuit that are based on the technology of the MDM (metal-dielectric-metal) structures. For the formation of the MDM - structures thin film of the dielectric with the thickness of 4-5 mkm was plated on the copper substrate by the high-frequency magnetron sputtering technique. This thin film represents multicomponent oxidize glass $\text{SiO}_2\text{-Al}_2\text{O}_3\text{-CaO-BaO-Mg-B}_2\text{O}_3$. Then a gold film that forms MDM-structure together with a substrate was also plotted. According to the structure oxidize glass recalls to the black colored ceramics with a mirror surface.

Electromagnetic parameters of the dielectric film (ϵ , $\text{tg}\delta$, ρ , U) have been measured on the MDM-structures that are thin film condensations, upper plates of which were formed by the way of deposition the metal layers through the phototemplates (Fig. 3).

Figure 3: The topology of the MDM conducting thin film.

Thus, TRA microcircuits were formed on the dielectric films. Cutting of the microcircuit and forming of the H-fine-line was done by the electro-spark machining technique on the machine-tool with digital operation.

3. Result. As it was mentioned above in the first cascades of the cryoelectronic TRA HEMT-transistors made by the leading Japanese firms are used. They are a combination of GaAs FET and HEMT. That absorb best achievements of the last 2 - 3 years to this field and successfully selected electrodynamics of the matching circuits of the microcircuit and TRA as a whole.

In foreign analogues HEMT - transistors are used in 1st and 2nd TRA cascades and in the cm waveband, where the amplification of the cascades is 3-4 dB higher in comparison with mm-waveband. In this connection there are certain reserves for the improvement of the obtained results while using the HEMT - transistor in the 2nd cascade. The results shown on the fig. 4 and 5 also on Tabl. 1 and Tabl. 2 give the possibility to make the conclusion that main parameters of the cryoelectronic TRA in the ranges of 21 - 23 GHz and 35 - 38 GHz are on the good level.

Table 1. Three cascade transistor amplifier on frequency 22 GHz

Noizy temperature Cascades number	T_n and K_v at the $T_p = 300K$	T_n and K_v at the $T_p = 18K$	T_n and K_v at the $T_p = 18K$ without hermoint- roduce
The first and the second cascades are done on HEMT-transistor of TOSHIBA firm ' IS-8911-AS	21,0 GHz = 220K 21,5 GHz = 210K 22,0 GHz = 195K	39K 38K 38K	29K 28K 28K
The fird cascade-transistor Joint-stock company "SATURN"	$K_v \sim 26$ dB	$K_v \sim 30$ dB

Figure 4: The frequency dependence amplification factor and noisy temperature transistor amplifier on frequency on 22 GHz ($T_p=18K$)

Table 2. Four cascade transistor amplifier on frequency 36 GHz

Noisy temperature	T_n and K_y at the $T_p = 300K$	T_n and K_y at the $T_p = 18K$	T_n and K_y at the $T_p = 18K$ without hermoit - roduce
Cascades number			
The first and the second cascades are done on HEMT-transistor of TOSHIBA firm ¹ IS-8911-AS	34,0 GHz = 270K 35,0 GHz = 278K 36,0 GHz = 288K 37,0 GHz = 290K 37,5 GHz = 290K	49K 45K 47K 49K 50K	34K 30K 32K 34K 35K
The first cascade-transistor Joint-stock company "SATURN"	$K_y \sim 24$ dB	$K_y \sim 31$ dB

Figure 5: The frequency dependence amplification factor and noisy temperature transistor amplifier on frequency on 36 GHz ($T_p=18K$)

- 4. Conclusion.** The most essential and interesting peculiarities obtained within the process of processing and testing of the cryoelectronic TRA samples are:
1. The transistor amplifiers without calculation of losses in pressure-seal feed-through have the equivalent noise temperature no more than $T_n \leq 25$ K in the range of 22 GHz and no more than $T \leq 35$ K in the range of 36 GHz.
 2. Perspectiveness of the elaborated construction of the TRA for the application in the range higher than 40 GHz is considered to be an important result.
 3. Obtained value of T_n can be improved to 10 - 15 %.

4. We have elaborated an engineering technique of designing waveguide - playing TRA construction in mm-bands that realize potential abilities of the bodyless HEMT - transistors in full. On the base of the data on modulus and phase of the S-parameters of the transistors optimum possibilities of the input and output resistance for the providing of the amplification factor have been obtained.

5. Assembling of the transistor was executed according to the instructions accompanying the passport of the transistors.

The high repetition of the electric parameters of the transistor was mentioned.

6. For the first time in Ukraine the samples of cooling TRA on the modern element base with the use of the achievements of the leading Japanese firms on HEMT - transistors elaboration have been obtained.

7. While selecting the circuit of the cryoelectronic TRA a possibility of its wide-scale application and in the first turn in the structure of large antenna global systems, satellite and space communications, radioastronomy and scientific researches has been considered.

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