# Ka BAND GaAs MMIC CHIPSET FOR SATELLITE COMMUNICATION PAYLOADS

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**ABSTRACT.**
The present paper describe a number of GaAs MMIC developed by Alenia Aerospazio for Ka Band satellite equipment application using a standard 0.25 PHEMT process. As did for Ku band applications these new MMIC can be used as building blocks for several new generation equipment. Low noise amplifiers and control functions have been implemented with good results showing the effectiveness of this technology for all future implementations.

## INTRODUCTION.

Application of MMIC technology in satellite equipment is already assessed in Ku band equipment. A number of equipment for several satellite applications (FSS, MSS, DBS) have been developed using this technology with excellent results both in terms of performances and yield [1]. New satellite services (as multimedia transmission) require functions in the range from 20 to 30 GHz not only because of the amount of the transmitted data, but also to overcome the saturation of the channels in the Ku-Band part of the spectrum. Moreover a huge amount of equipment having small dimension and weight is foreseen for the next years. In this frame the application of MMIC technology appears to be mandatory.

## Ka Band EQUIPMENTS.

On the basis of the main mission objectives of satellite systems several architectures can be envisaged. The transparent configuration is well suited, for instance, for DHT-TV based services where a wide range of transmission data rates without on-board switching is requested. The regenerative payload configuration is optimally suited for multicarrier and/or multibeams configurations in which flexible routings need. An Example of Ka Band transparent repeaters is shown in figure 1. As in Ku band payloads, the most attractive application for MMICs lies in the channel amplifiers (CAMP) and linearizers (LCAMP) which, depending on the complexity, are present in high quantities. Receiver modules (RX), integrating LNAs and downconverters, are a further useful applications for the MMICs.

When using MMIC technology the first tradeoff to be done is between modularity and integration scale, identifying a minimum number of building blocks necessary to implement different equipment. A set of MMIC has been identified to cover the needs of the CAMP, LCAMP, RX whose microwave sections are fully MMIC based.
- LNA: are extensively used in all the mentioned equipment. Nevertheless, RX operates at 30 GHz while CAMPs and linearizers operate at 20 Ghz. As a multiproject foundry run was foreseen for this development, it was found more convenient to optimize two MMICs at 20 GHz and 30 Ghz respectively rather than develop a single MMIC with such a large bandwidth.
- VA: is used in CAMP as gain control element and in LCAMP and RX as element for alignement and gain compensation.
- MPA is used in CAMP and RX to improve the linearity of the overall equipment.

## TECHNOLOGY DESCRIPTION.

A standard 0.25 um low noise PHEMT process has been chosen to develop all the circuits. As well known, for a multiproject run, the higher is the type of MMICs on a single mask the lower is the total yield. On the other hand , in order to have the highest probability of success, more than one version for each circuit was developed increasing the number of processed wafers. Raytheon Co. ADC was chosen as foundry and A total of 6 four inches wafers were processed at the same time. Typical process parameters are: Ft = 50 GHz , minimum noise figure of 1.5 dB at 30 GHz, Idss=120mA/mm; Gmp=375 mS/mm; Vp=-0.7 Volts; Vbgd=-10. The chosen process is already space qualified and it has already been extensively used for other satellite on board equipment [1] ,[2].

## MMIC DESCRIPTION.

Described below are 3 MMICs that have been developed in a first multiproject run. At the time of writing other MMICs are under development for the same overall applications:

- 20 Ghz Phase shifter. (PS20)
- 30 to 20 Ghz down converter Mixer (DMX3020)
- 10 Ghz VCO.
- 20 Ghz MPA.

### 20 GHz Low Noise Amplifier.

Source feedback was used to reach optimum noise figure and good return loss at the same time. A four stage configuration was necessary to get the specified gain-bandwidth performances (20 dB over 17-22 GHz). Each stage is self biased to allow the use of a single bias at equipment level and reduce the drift with temperature. Gate voltage has been properly chosen to maximize the stability of each stage. In order to recover for the pinch-off voltage variations, a series of groundable pads are available on MMIC to properly adjust the source resistors. On wafer measurements and layout are reported in figure 2. Chip dimensions are 3x2 mm.

### 30 GHz Low Noise Amplifier.

The approach was similar to 20 GHz LNA. Again self biased configuration has been used to allow compatibility with the other circuits at equipment level. By optimizing the FET periphery of each stage, a three stages configuration was sufficient to achieve the specified gain (15 dB) keeping the power consumption within the specifications.

Source feedback was used in the first stage to get at the same time good input matching and noise figure. The same configuration has been repeated in the other two stages to optimize the overall performances.

In the layout design of this circuit some particular solution has been introduced to minimize the parasitic capacitance and inductance through ground. All the Viaholes have been put below the bypass capacitors where possible.

On wafer measurements and layout are reported in figure 3.

### 20-30 GHz Variable Attenuator.

A simple configuration based on two shunt cold FETs embedded within a pair of Lange Couplers has been implemented. Enhancing a concept already published [3], the gate lengths of the two FETs on each branch of the circuit have been chosen in order to have a more linear behavior of the attenuation vs. control voltage. Resistive dividers have been implemented on the chip itself to feed the two FETs with different voltages and have the possibility to use both negative or positive control voltage. In any case the control is through a single bias. Layout was particularly studied to minimize all the parasitic effects. Accurate modeling of cold PHEMT was necessary because of high parasitics at 30 Ghz.

## SIMULATIONS AND MEASUREMENTS.

Simulations have been performed using commercial available software. Passive and active elements have been modeled using data extracted from several measurements. Modified Materka model was used for non-linear model of PHEMT.

Due to the high operation frequency, the effect of the bonding wires/wafer probe have been properly taken into account during the simulation and the maximum allowed value for was checked.

Small signal measurements have been performed 100% on wafer while non linear and noise measurements were performed on sample basis on fixture.

Figure 2a and 2b show the 20 Ghz LNA simulated and measured gain. Figures 3a and 3b show the measured and the obtained noise figure respectively. On wafer measured noise figure is 1 dB higher than expected. Further optimization can be obtained changing the bias point of the active devices or by off-chip tuning at the input. The above considerations are also applicable for the 30 Ghz LNA whose simulated and measured performances are shown in Figures 4 a, 4b, 5a, 5b, respectively.

Results for 20 Ghz variable attenuator are reported in figures 6a and 6b. Also in this case it is possible to see the very good accordance between simulations and measurements. Since one of the possible use for this device is inside the linearizer it has carefully characterized in terms of linearity under compression. Figure 7b shows the results for compression measurements.

## YIELD AND RELIABILITY.

Typical Yield for this process is 50% at the completion of the on wafer measurements. Figures 3b, 4a and 8a give an Idea of the dispersion obtained on the whole Lot (6 wafers) in that they reports the average, max. and min. value for NF and gain respectively. The histogram reported in figure 8b show, for the present wafer run, dispersion around the average value in terms of DC current for 20 Ghz LNA.

Reliability of used technology was already demonstrated in the frame of Ku Band MMIC development program in which two different LNAs were developed using the same PHEMT process mentioned in this paper. Table 1. summarize data about some parameters of the mentioned MMIC as extracted from relative test reports [4], [5]. Several tests have been performed on different production lots showing no appreciable degradation during more than 1500 hr. accelerated life test. Comparison between collected data and Arrhenius plot for the same technology shows that predicted MMIC life is: higher than $10^5$hr. @ 110 °C junction temperature and higher than $10^8$hr. @ 50 °C.

**CONCLUSIONS.**

A new set of MMIC and their use in Ka band equipment was presented. This paper demonstrates that GaAs integrated technology is not only assessed in Ku band, but is also effective for all the present Ka band satellite equipment. The obtained results are the basis for the development of truly competitive satellite microwave equipment.

**ACKNOWLEDGMENTS.**

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**References.**

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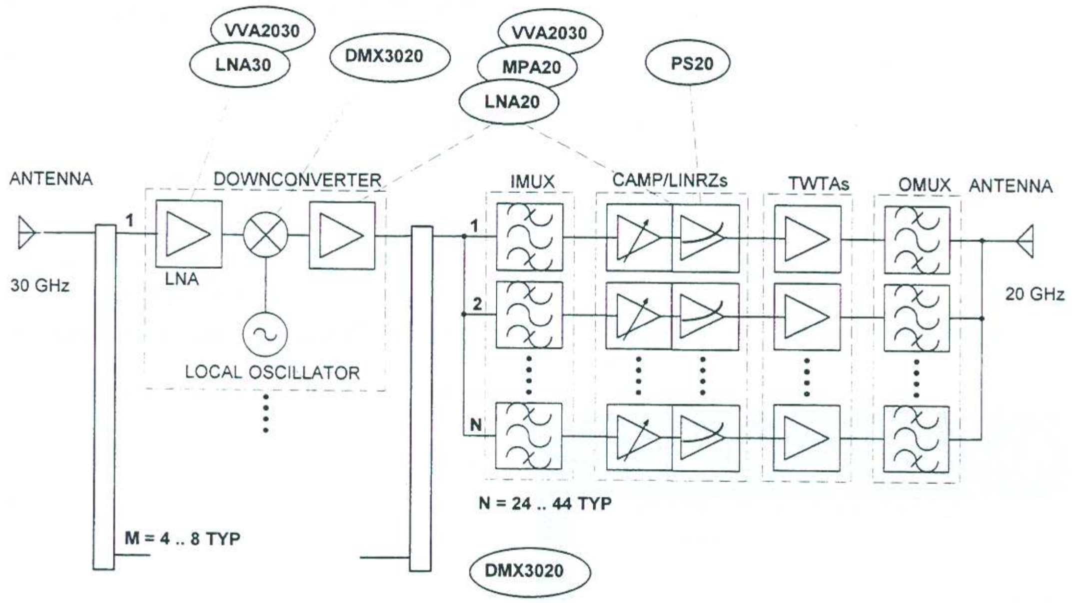


*Figure 1 Generic transparent payload architecture including MMIC usage plan.*

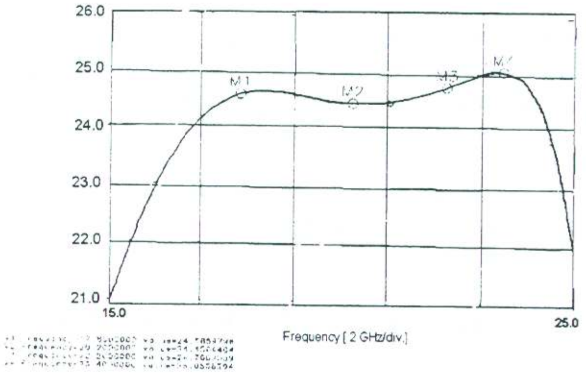


*Fig.2a:20 Ghz LNA: Simulated Gain*

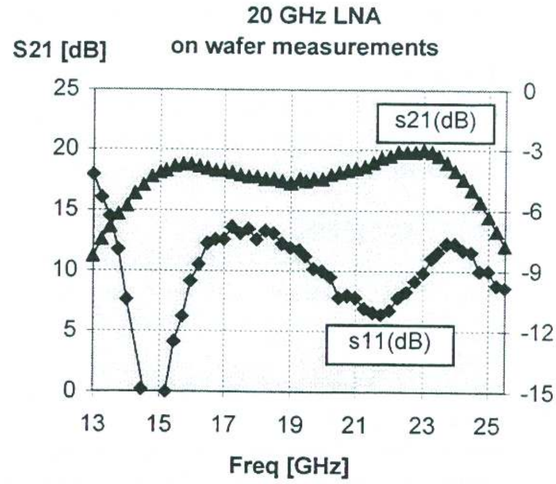


*Fig. 2b:20 Ghz LNA On wafer measured gain*

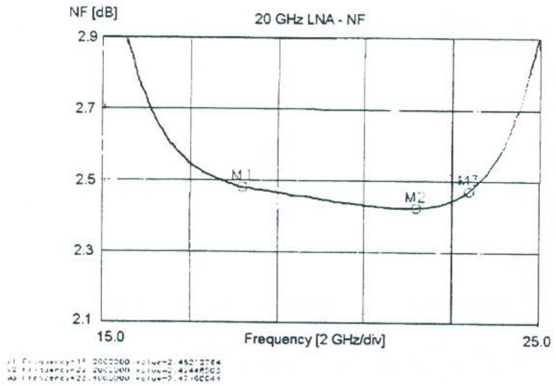


*Fig. 3a:20 Ghz LNA Simulated Noise Figure*

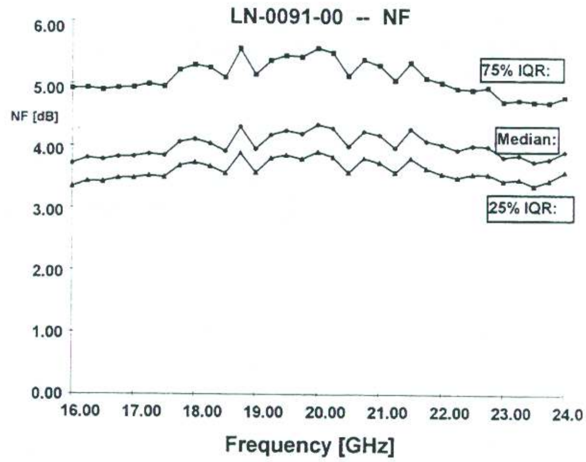


*fig.3b: 20 Ghz LNA Measured Noise Figure*

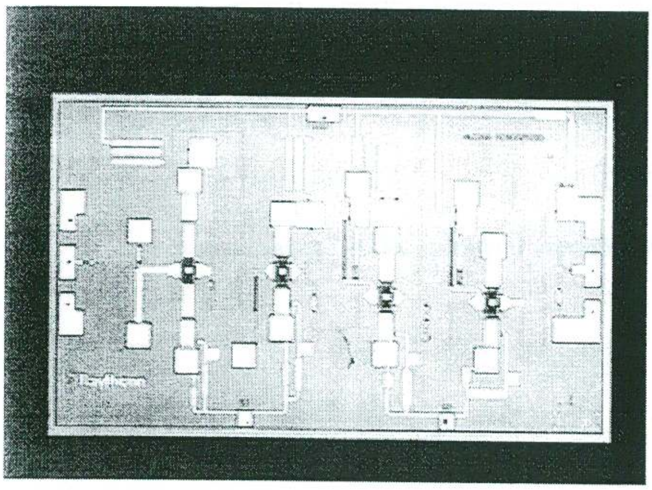

*Fig.3c - Layout of 20 Ghz LNA*

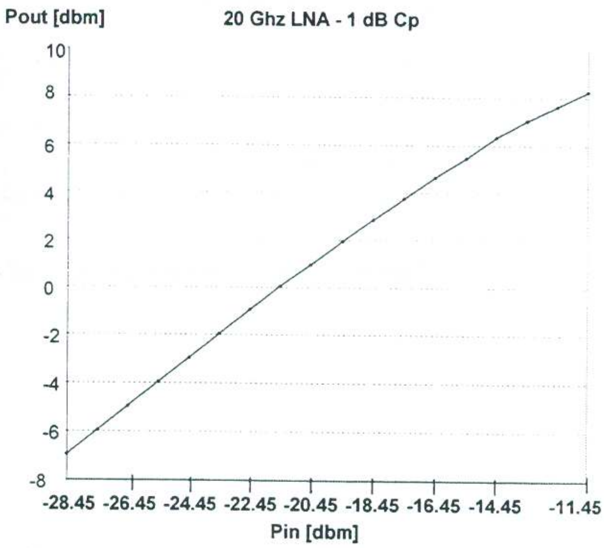


*Fig.3d - 20 Ghz LNA: Compression measurements*

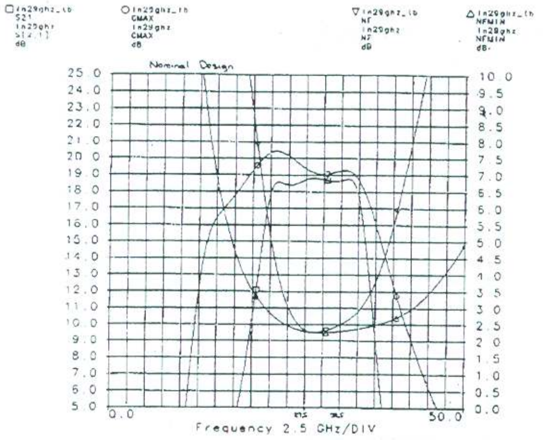

*Fig.4a- 30 Ghz LNA: Simulated performances*

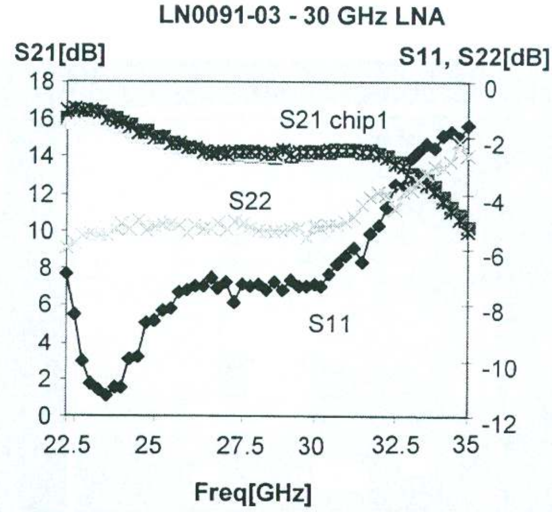


*Fig.4b: 30 Ghz LNA Measured performances*

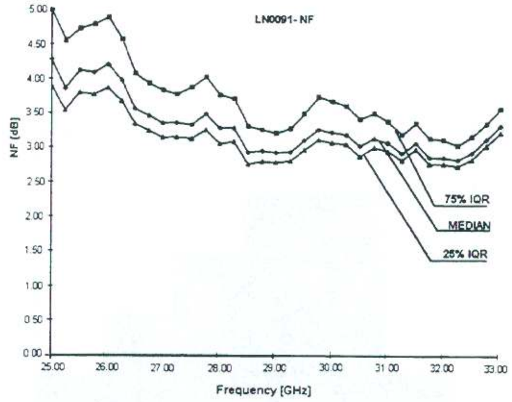


*Fig. 5a - 30 Ghz LNA : Measured Noise Figure*

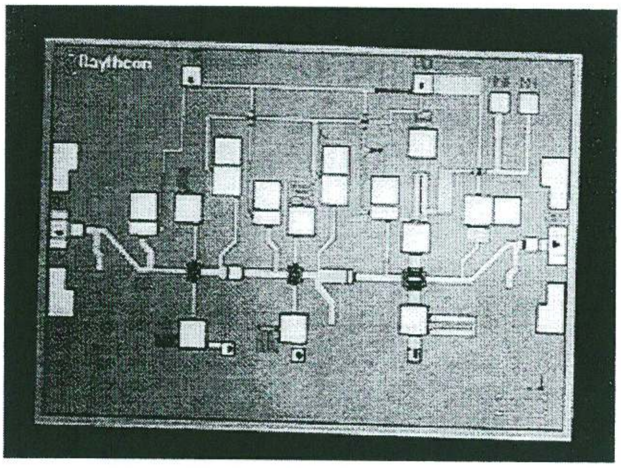

*Fig.5b - 30 LNA layout.*

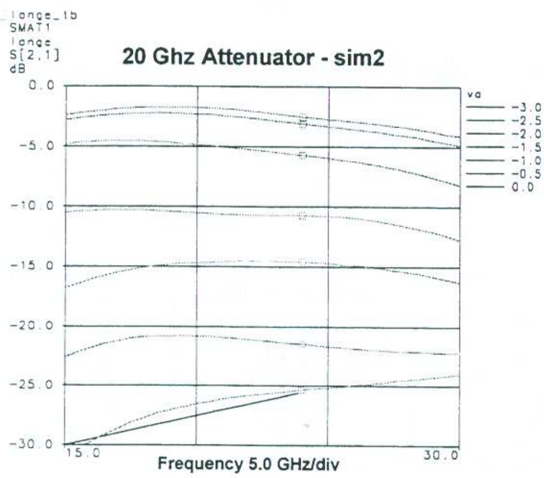


*Fig.6a - 20 Ghz Variable Attenuator: Simulated performances.*

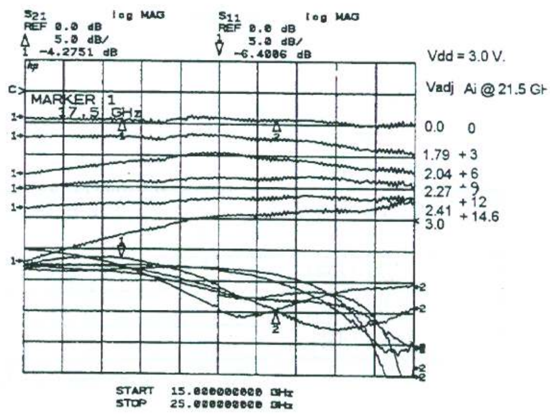


*Fig.6b - 20 Ghz Variable Attenuator fixtured measurements*

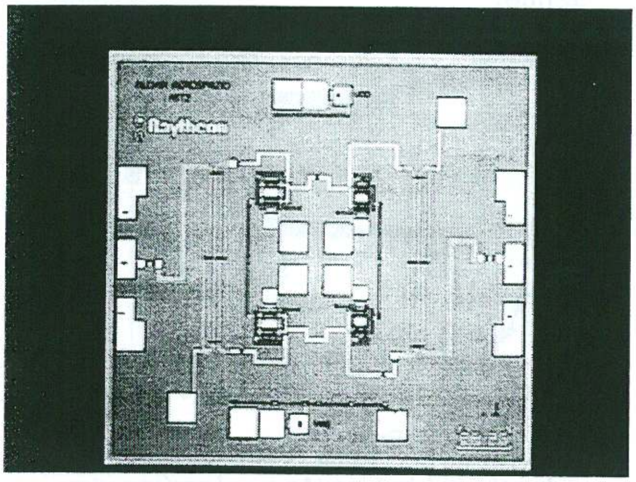

*Fig. 7a - 20 Ghz Variable Attenuator: Layout*

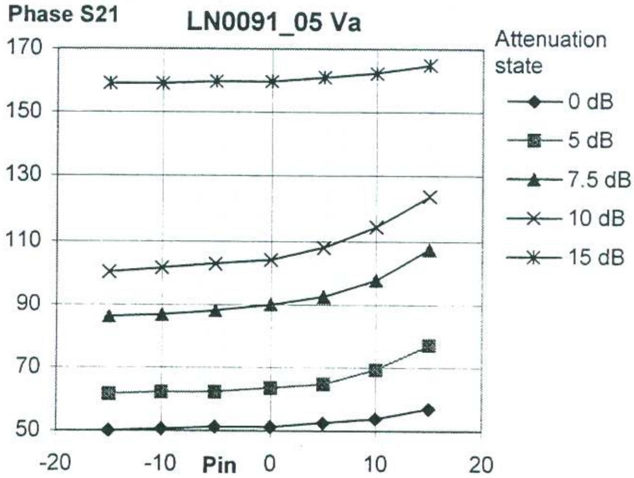


*Fig. 7b - 20 Ghz VA: S21 phase variation at compression.*

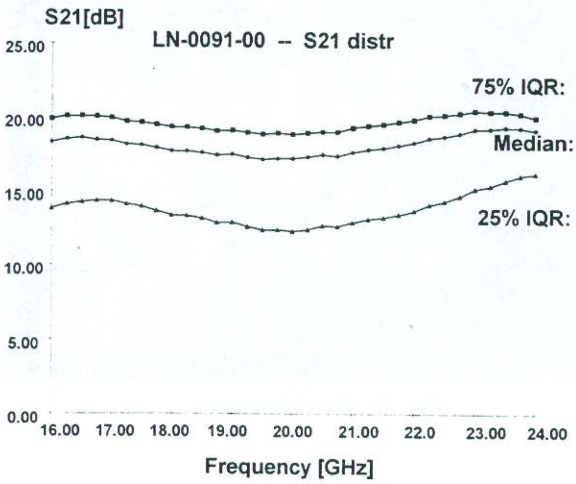


*Fig.8a - distribution of 20 Ghz LNA gain over three wafers*

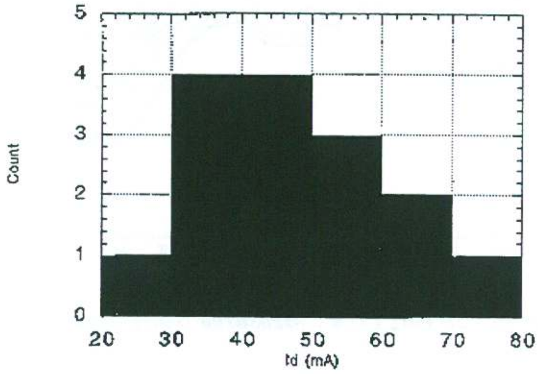


*Fig.8b - distribution of 20 Ghz LNA DC current over four wafers*

| Parameter | Pre B.I. | Post B.I. ( 240hr.) | Post life (1500hrs) | Delta |
|---|---|---|---|---|
| S21 [dB] | 11.20 | 11.43 | 11.54 | 0.34 |
| Idd [mA] | 42.50 | 42.90 | 43.00 | 0.5 |
| NF [dB] | 2.99 | 3.05 | 3.06 | 0.07 |

*Table.1: summary of life test performed on PHEMT based LNA*