KA-BAND COAXIAL AND WAVEGUIDE WIDE TEMPERATURE RANGE COMPENSATED LOW NOISE AMPLIFIERS

R.Pardini, A.Miceli

MICREL S.p.A.
Via A.Einstein, 26 50013 C.Bisenzio, Firenze, Italy

ABSTRACT

This paper describes the design and manufacturing steps of two different Ka-band microstrip six stages low noise amplifier configurations, operating over the temperature range of -40/+125 °C.

The preliminary performances of these two components,in the Bandwidth of 400MHz centered at 35GHz, are: Noise Figure less than 3.8dB at 25 °C temperature with a 2.9 dB NF first stage and a dual temperature compensation network.

Gain is in excess of 20dB and In/Out VSWR better than 1.5:1.

Two different prototypes (i.e. waveguide WR28 and coaxial K-connector) are discussed.

1. INTRODUCTION

A six stages LNA compatible with Space, Airborne, Ka-band radiometer front-ends and Missile-guidance systems has been preliminary designed as a part of a self supported technological upgrade programme [1].

The major objective of this programme has been the design and manufacturing of high performance millimeter-wave low noise amplifiers.

This paper decribes two concrete and practical projects, implemented in a modular assembly, without any interstage matching and optimization at Ka-band.

Low noise figure and good input VSWR are suitable specs to optimize antenna-performance moreover wide operative temperature range is a further achievement for military applications.

Gain in excess of 20dB allows to perform a good successive front-end components (i.e. mixer, filters, IF amplifier etc.) noise figure contribution reduction.

A particular biasing technique is necessary to compensate six stages gain vs temperature variation.

Two different prototypes (waveguide WR28 and coaxial K-connector) have been manufactured in order to compare electrical performances and to achieve a complete system-interface versatility.

A waveguide transition has been implemented developing two WR28-microstrip transitions which must be simple, low loss and repeatable.

2. AMPLIFIER MODULES DESIGN

The selected active device is a conventional HEMT (no Indium in the active layer) with 0.25um gate length.This device is available in chip form with a good cost/performances compromise.

De-embedded Vector Analyzer measurements of chip S-parameters up to 26GHz confirmed good agreement with data-sheet values report.

The measured noise parameters available from data-sheet up to 26GHz were extrapolated up to 40GHz by using a suitable linear noise model [2], in order to evaluate the HEMT capability and to design the low noise stage input matching network.

The choice of the proper design approach is related to find out the right compromise between minimum noise figure and input matching.

A balanced configuration, which performs good return losses, was not implemented because of its cost (double stages number), its large transverse layout dimension critical to operate below the cutoff of the fondamental loaded cavity-mode, and for the intrinsic losses of 90° hybrid structures at Ka frequencies.

Moreover, the design of interstage networks was performed in order to avoid the use of drop-in isolators beetwen two adjacent modules.This was necessary because, for the wide operative temperature range required, drop-in isolators are critical and expensive devices. For the same reason, a single-ended configuration with input isolator was discarded.

A single-ended without input isolator configuration was selected because of its semplicity and lower input losses.

A required 5 number of stages, to perform 20dB gain at least, was extimated.In consequence of that a temperature compensation and a further gain stage, to recover pin diode attenuator losses, were required.

The matching networks, after a coarse design by the well known Smith-chart metods, were optimized by ACADEMY (EESOF Inc.) over a widest bandwidth.

For the noise figure optimized first stage (i.e. the first stage of the LNA) the possibility of introducing source series feedback to allineate the optimum noise figure point and the optimum input matching point on the Smith-chart was investigated and the optimum length for the source bond wires resulted [1].

Suitable band of operation was performed by the implementation of distributed matching networks among adjacent stages.

A particular care was required to perform very effective damping networks against possible oscillations outside the amplifiers operative bandwidth, again to avoid the use of drop-in isolators.

For this purpose damping networks implemented by resistive pads and reactive distributed components were tuned to suitable frequencies as much as possible adjacent to the matching networks whithout a appreciable degradation of the Noise Figure and Gain system performances.

Before the final assembly into the LNA housing, the modules were tested on a test-jig; the achieved results, without any trimming, were in good agreement with the computer simulations.

The amplifiers are composed by a module optimized for the Noise-Figure, two modules optimized for Available Power Gain and a Pin-Diode Attenuator for the gain variations vs temperature compensation.Each module is composed by two stages, assembled on a single carrier.

2.1 GAIN COMPENSATION AND BIASING CIRCUITS

A pin-diode attenuator, designed in balanced configuration, was selected for the minimum insertion loss compatibily with a wide dinamic range in order to implement an absorbitive configuration and compensate the gain variation vs temperature.

Gain variation vs temperature was extimated about 15dB over the operative range of -40/+125 °C.

The absorbitive cofiguration ensured good interstage-matching and effective spurios frequencies damping.

In addition a second gain compensation was performed acting on the last four stages biasing.

At room temperture the drain currents (Id) are not selected for the maximum available gain; the biasing circuit is designed to decrease the HEMT gate-source voltages (Vg) with temperature increasing and so the gain also tends to increase with Id. By using this technique, a partial gain/temperature compensation of 4dB was possible.

A similar result could be achieved by a suitable temperature compensation of Drain-Voltages. This technical approach was not considered because it required a more complicated biasing-network than the other one.

In consequence of gain-temperature compensation 0.3dB lna noise figure degradation resulted.

In fig.1 a block-diagram of the biasing technique is given.

2.2 LNA HOUSING AND WG/COAX-TRANSITIONS DESIGN/MANUFACTURING

The housing was designed in order to allow a minimum of trimming on the cascaded amplifier modules and the sealing of the active devices with inert gas (Nitrogen).

This solution allows to hybrid thin-film technology, at Ka-band, to confirm it's low cost in small and medium volume productions.

The transverse channel dimension, where the amplifier modules are fixed, was selected narrow enough to operate below the cutoff of the fondamental loaded cavity-mode.

Each module is composed by two stages, assembled on a single kovar carrier.

All the modules have been implemented in thin-film technology by using chip and wire components on Al2O3 substrate 10mil thickness.

Particular care was assigned in the process of welding ceramic substrates and Hemt devices to gold plated kovar carriers, by using Sn-Au eutectic alloy.

The coaxial transition was implemented welding the connectors glass-bead in the housing-walls and using a short microstrip to connect it to the amplifier modules.

The waveguide transition was implemented developing two WR28-microstrip transitions. The design approach was for a simple E-field probe, orthogonal to the z-axis of the waveguide.

This solution, though not "in-line", has the advantages of semplicity, low loss and good repeatibility. The transitions were tested "back to back" through a 50ohm duroid microstrip.

A quick trimming of the back-short position, by using a milling machine during a stage of bread-boarding measurements with an HP8510 network analyzer and a suitable choice of the probe minimized the Insertion Losses down to 0.2dB for each transition and optimized the Return-loss to less than -20dB.

The biasing circuits, included the pin-diode driver, were realized by the use of SMD packaged components.

This allowed an easier assembling and testing in order to optimize, above all, the pin-diode driver.

3.RESULTS AND GRAPHIC PRESENTATION

The amplifiers are composed by a module optimized for the noise-figure (NF=2.9dB, G.A.=7.5dB), two modules optimized for available power gain (NF=3.4dB, G=8.5dB)_and a Pin-Diode attenuator (I.loss=2.5dB, Isolation=-12dB)_for the gain variations vs temperature compensation.

LNAs noise figure of 3.5 dB was performed without temperature compensation.

In fig.2 a characterization of the attenuator I.loss versus Id (pin diode current) is given.

Waveguide/microstrip transitions characterization, in the band from 26.5GHz to 40GHz, is showed in Fig.3.

Neglecting microstrip line loss, the curve traslates into a dissipation loss of less than 0.2dB for each transition.

Fig.4 shows the compensated LNAs small signal gain (20dB±0.5dB in the operating bandwidth) and the input/output VSWR (better than 1.5:1) versus frequency at ambient temperature (+25 °C) (waveguide version).

Compensated small signal gain and input/output VSWR, vs frequency and over the operative temperature range, are showed in Fig.5 .

The temperature gain variation is only ±1dB while the gain flatness is less than 1dB at every temperature.

In Fig.6 is showed the NF which is better than 3.8dB (waveguide version).

The implemented amplifier modules dimensions are 5mm X 14mm and the LNA prototypes are 100mm X 39mm X 35mm for both versions coaxial and waveguide (for the coaxial version the connector are included).

A reduction of dimensions is possible just replacing bias circuit by an hybrid one.

In fig.7 a schematic top view of a WG coverless LNA is given.

4.CONCLUSION

Two different prototypes of wide range temperature compensated low noise amplifiers (i.e. waveguide WR28 and coaxial K-connector) has been discussed.

The preliminary performances of these two components,in the Bandwidth of 400MHz centered at 35GHz, are: Noise Figure less than 3.8dB at 25 °C temperature,__Gain in excess of 20dB,__Gain variation vs Temperature (-40/+125 °C) less than ±1dB_and Input/Output VSWR better than 1.5:1 over all the temperature range.

5. ACKNOWLEDGMENT

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6. REFERENCES

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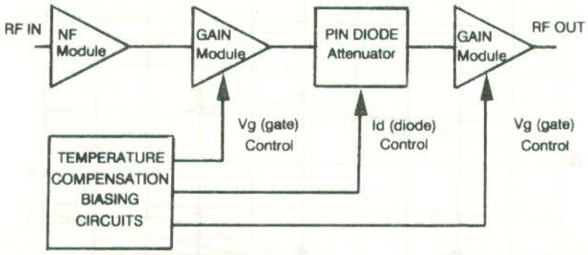

FIG.1 Temperature compensation biasing techique.

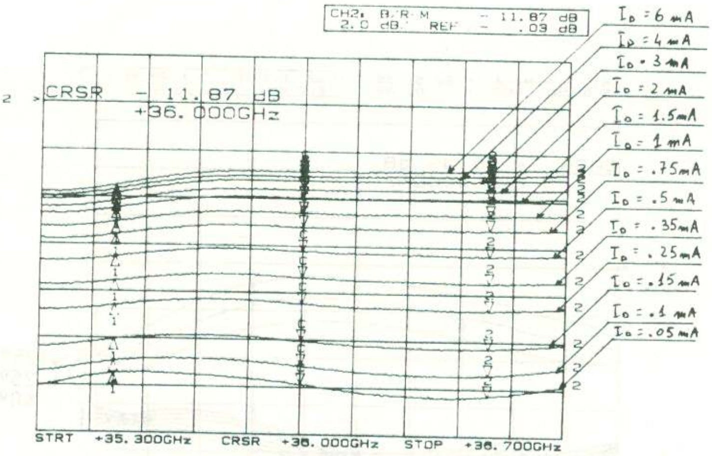

FIG.2 Pin diode attenuator I.loss vs Id (diode current).

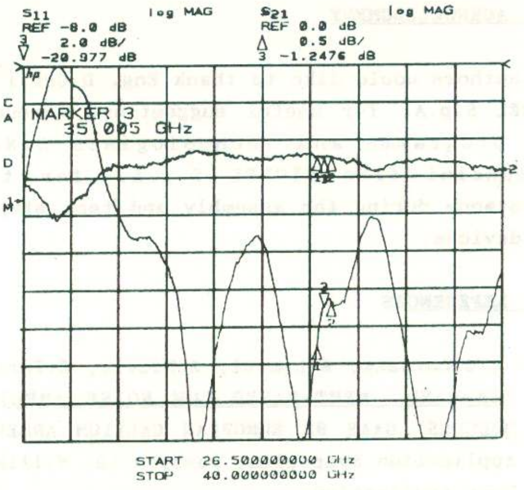

FIG.3 Two waveguide/microstrip transitions back to back connected.

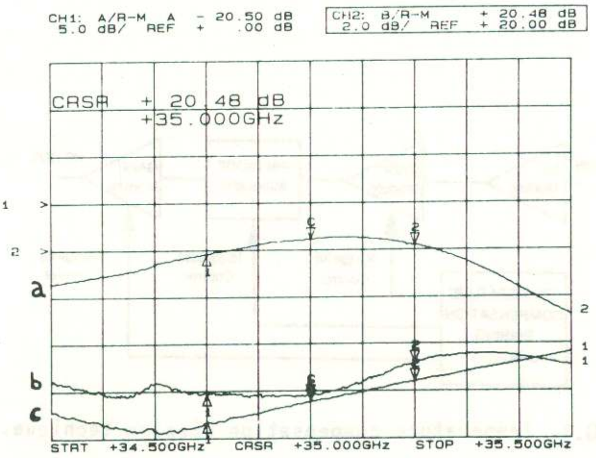

FIG.4 WG-LNA (T=+25°C)
a) Gain, b) I/P VSWR, c) O/P VSWR.

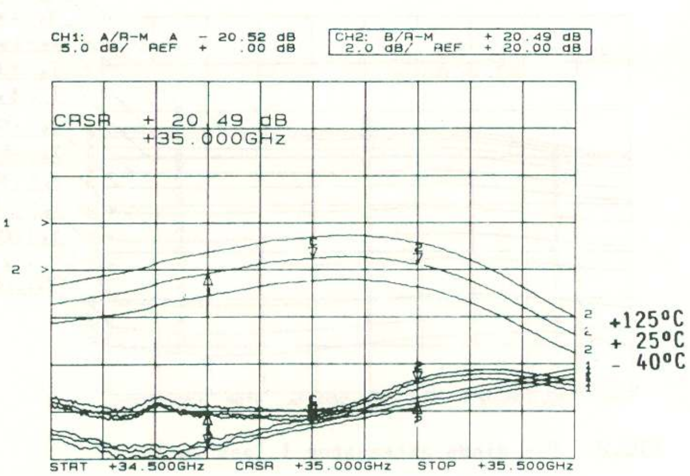

FIG.5 WG-LNA performances vs temperature and frequency.

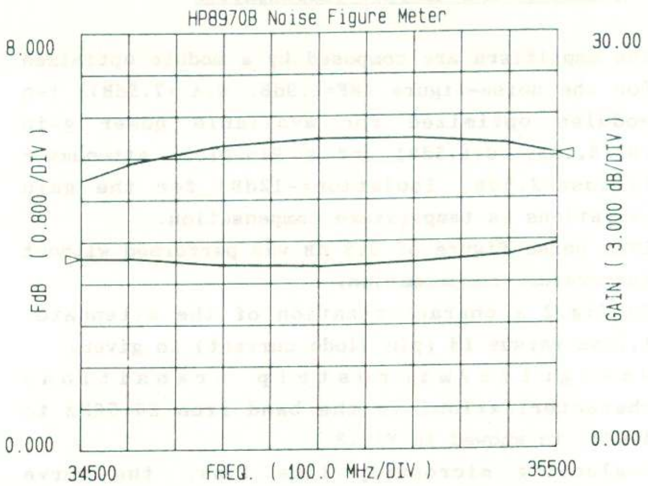

FIG.6 WG-LNA (T=+25°C) noise figure.

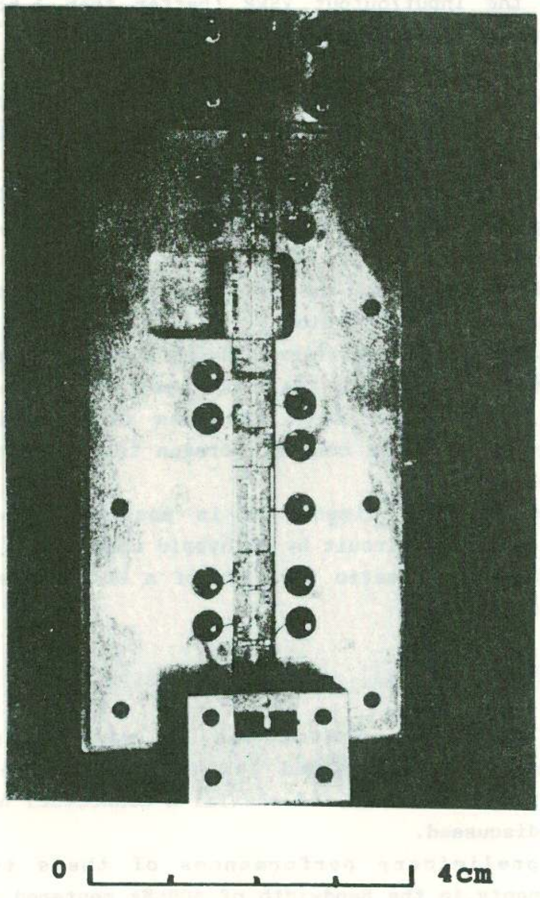

FIG.7 Top view of a WG coverless LNA.