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Development of Ku-band Low Noise Amplifier for Satellite Transponder

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Abstract /11 P

This paper presents the development of a Ku-band Low Noise Amplifier with the Noise figure of 1.4dBmax, the gain of 35dB, and the In/Out Return Loss of -22dB/-18dB in the frequency range from 14 to 14.5GHz for Satellite transponders.All RF components were assembled using a hybrid technology with 15-mil thin-film substrates. The mechanical and thermal design of the housing was performed considering a vibration and a vacuum of space environment

Key words : Satellite Transponder, LNA, Ku

I. Introduction

The electrical performance of the low noise figure and the stable mechanical design of the housing are key parameters of the Low Noise Amplifier (LNA) for satellite transponders[1]. This paper presents the development of a Ku-band LNA with the Noise figure of 1.4dBmax and the gain of 35dB, the In/Out Return Loss of -22dB/-18dB in the frequency range from 14 to14.5GHz for Satellite transponders. The functional block diagram of the LNA is shown in Figure 1. It is consists of an Waveguide Isolator, Waveguide to Microstrip line transition, 3-stage low noise amplifier, a fixed attenuator for gain level control, a single stage low noise amplifier, and a drop-in isolator for improving the output VSWR. For the design of the single stage LNA, series feedback techniques were used with the source wire length controls. The bandwidth of the gain for the single stage LNA was achieved more than 2GHz. All RF components were assembled using a hybrid technology with 15-mil thin-film substrates. The mechanicaland thermal design of the housing was performed considering a vibration and a vacuum of space environment.

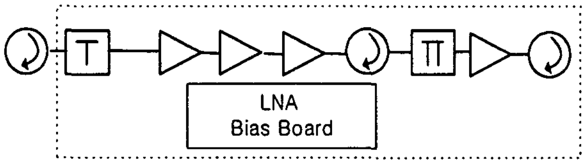

Fig.1. Functional block diagram of the Ku-band LNA.

II. Electrical Design

The transition of waveguide (WR75) to microstrip line was designed using the 3D EM simulator (HFSS) to have a maximum return loss [2][3]. The HFSS model of the designed transition is shown in Fig. 2. The probe with larger radius is

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attached at thetransition probe for broadband frequency characteristics. In/out return losses are higher than 30 dB at the design. Four gain stages are four identical single stage and noise-matched amplifiers based on 0.15 m Fujitsu (FHR20x) p-HEMT chip. The chip is conditionally unstable in the required frequency band. The series feedback techniques were used for improving the In/Out VSWR and noise figure performance simultaneously. The schematic of the LNA is shown in Fig. 3. In general, an inductor is inserted between the source and ground for the series feedback. But itis difficult to assemble the discreet inductor and a bare HEMT chip at the same alumina substrate. At the high frequency the bonding wires act as a good inductor. The single stage LNA is designed with the series feedback using the sourcebonding wire length control and noise matching technique. Four source wires are bonded with 1mm wire length. The wire length can be exactly controlled by bonding machine. The gain and noise figure of each stage were 10 dB and 1 dB, respectively. The available bandwidth was achieved more than 2GHz. The fixed attenuator is a balanced type attenuator with Lange coupler. The attenuator provides the required gain of the LNA and avoids too high power level into the following mixer in the downconveter module.It has three ports with resistors at their end side. Each port connection determines the attenuation level. Fig. 4. and Fig. 5. show the schematics of the attenuator and the attenuator level for each port connection, respectively. Drop-in isolators are used to minimize interstage mismatches and ripple and to improve the output VSWR. DC bias circuit driving the LNA consists of the regulator circuit with the negative voltagepre-apply circuit and the driving circuit supplying 2V of drain voltage and 5mA of drain current for each LNA stage. The used material and process of the bias board substrate were an Alumina(Al2O3) with 1mm thickness and a thick film technology, respectively. Fig 6. shows the schematics of the bias circuits.

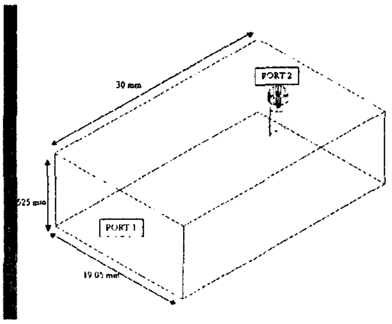


Fig.2. HFSS model of the transition

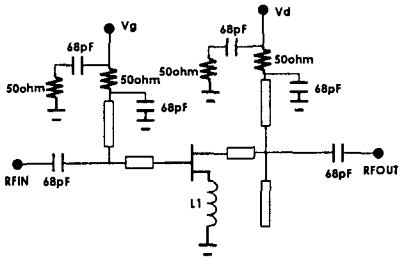


Fig.3. Schematics of single stage LNA

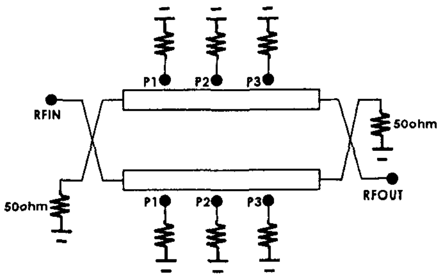


Fig.4. Schematics of Lange Attenuator

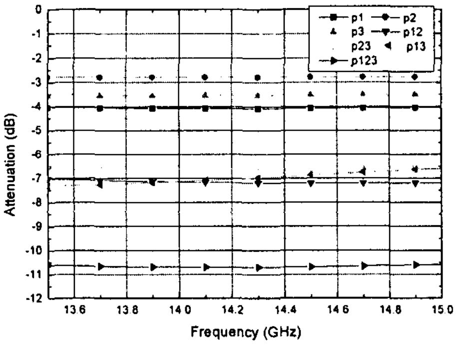


Fig. 5. Attenuation level of the Lange Attenuator for port connection (p12 means that p1 and p2 are connected at the main line)

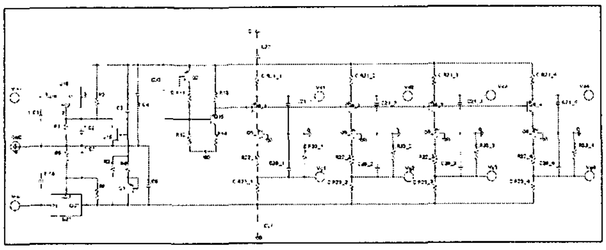


Fig.6. Schematics of the bias circuit of the LNA

III. mechanical design and measurement

Fig. 7. shows the assembly drawing and its sequence. The housing is machined from aluminium alloy of AL6061-T6. The material of the carriers is Kovar on which the Eutetic bonding is possible between the carrier and the substrate. The housing and covers are Nickel plated. The EMI filters of 5nF are used for prevention of unwanted RF noise through the DC bias board. There are two RF cover. One is for the RF covering and the other is for the laser welding. A mechanical and a thermal analysis were performed for the designed housing. The mechanical analysis shows the housing has resonant frequency of 1759Hz that is greater than 100Hz (requirement) and enough margin of safety under mechanical environmental conditions. The thermal analysis shows the heat flux density of 0.02W/cm2 and the predicted maximum temperature of 76.3oC. All parameters meet the requirement of 0.4 W/cm2for the heat flux density and 125oC for the maximum derated temperature.Fig. 8.(a) and (b) are the picture of the RF side and DC side, respectively, of the developed LNA module. As shown in Fig. 8.(b), DC bias board was conformal coated with polymer for preventing the outgasing in the vacuum environment.

Fig. 9. shows the gain and return Loss performance of the developed LNA module. For exact calibration of the used Vector Network Analyzer (Agilent 8722ES), 20dB fixed attenuator was used. The gain and In/out return loss are 34.80.3dB and higher than -26dB/-18dB, respectively. As shown in Fig. 10., the Noise Figure is lower than 1.4dB in the frequency band of 14~ 14.5 GHz at ambient temperature.

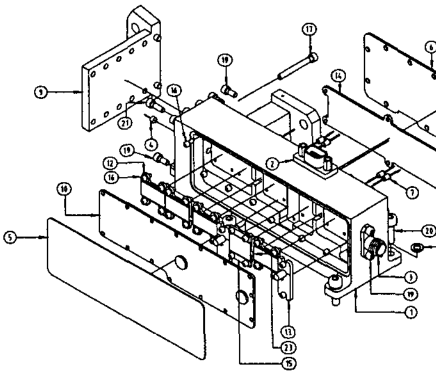
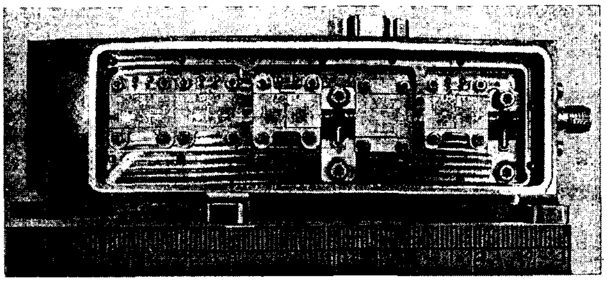
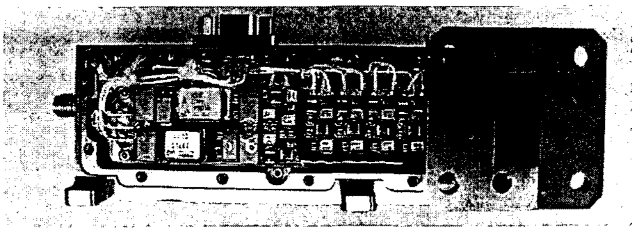


Fig. 7. Assembly drawing of LNA module (2: 9pin D-sub connector, 3: Venting hole, 5: Outercover, 7: EMI filter, 10: Inner cover, 19: SMA connector)



(a) RF side of LNA module



(b) DC side of LNA module

Fig.4. Picture of the LNA module

IV. conclusion

This paper described the electrical and mechanical design of a Ku-band Low Noise Amplifier for satellite transponders. The single stage LNA was designed using the series feedback technique with source wire length control. For the designed housing, the mechanical and thermal analyses wereperformed to confirm the stable structure and the good thermal stability. The electrical performance of the developed LNA shows the noise figure of 1.4dBmax, the gain of 35dB, and the In/Out Return Loss of -22dB/-18dB in the frequency range from 14~ 14.5GHz.

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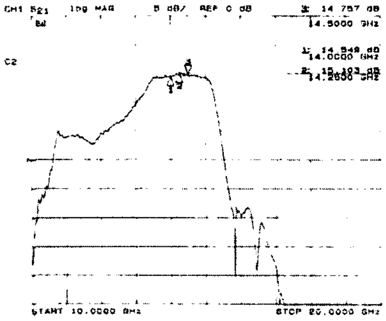

Fig. 9. The gain performance of the LNA module

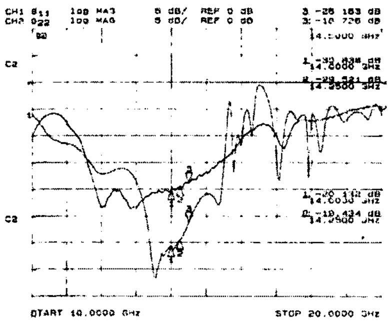

Fig. 10. The return loss performance of the LNA module

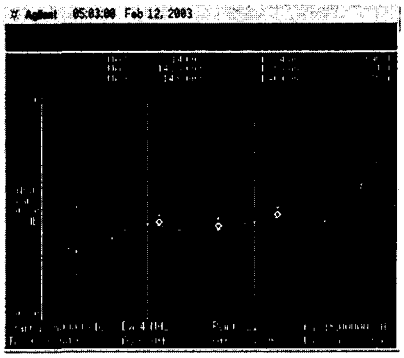

Fig. 11. The noise figure performance of the LNA module

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