AN ADVANCED TECHNOLOGY L-BAND LIGHT WEIGHT RECEIVER FRONT-END

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ABSTRACT

An advanced technology L-band receiver front-end was designed and built using MIC and MMIC technologies. This unit carefully utilises the advantages of both technologies in producing a miniaturised module with state-of-the-art performance. The complete front-end section comprised MIC LNA (Low Noise Amplifier) and three single ended, easily cascadable MMIC gain stages. The typical performance of the unit is 0.70 dB NF (noise figure) at 20°C and gain exceeding 40 dB.

1. INTRODUCTION

In recent years greater attention has been given to the application of MMIC technology in space hardware as it offers large reductions in size and mass coupled with improved reliability. The advances in MMIC technologies both in the field of foundry/manufacturing techniques and electrical design has resulted in development of wide range of multifunction chips often referred to as "super components". Although these components offer a tremendous size reduction associated with good performance, the typical RF response falls short of similar MIC units. For example, sub-1 dB NF at L-band is readily achievable in designs based on MIC technologies whereas 1.5 dB NF in an MMIC LNA stage would be demanding [1], [2]. This paper presents the optimum approach where both technologies are combined to produce state-of-the art performance in a minaturised solid state L-band receiver front end unit.

2. MIC LNA STAGE DESIGN

The design and performance of the input stage is highly critical as it dominates the NF performance of the unit. A novel feedback design technique was used in the development of the LNA which realised simultaneous optimum noise figure and input match. Hence, neither an isolator nor a balanced configuration are required which results in a compact circuit with no front-end coupler or isolator losses to degrade the receiver NF. In the design of the LNA two distinct feedback components are analysed, extrinsic - feedback loop defined by series or shunt feedback component and intrinsic - from the reflected signal arriving at the output port. The developed matching network based on this relatively complex feedback configuration converges S11* towards Γ_{opt} thus enabling realisation of simultaneous NF_{opt} and very good input match. The test data showing the characteristics of the LNA over 1.0 GHz to 1.8 GHz are given in figures 1 (a), (b) and (c). The summary of the measured data is as follows:-

Design b.w.	MHz	1560 - 1620
NF at 20°C	(dB)	0.65
Gain	(dB)	15.80
Input Match	(dB)	> 20

The LNA stage was temperature cycled over -5°C to +55°C. The NF and Gain vs. temperature coefficients were measured as 0.007 dB/°C and -0.008 dB/°C respectively.

3. MMIC AMPLIFIER DESIGN

The design was based on variable gate width FET model. The gate to source capacitance, C_{gs} and drain to source resistance R_{ds}, were defined as directly and inversely proportional to the device gate width respectively as given in equations (1) and (2).

$$C_{gs} = \frac{w_g}{300} \times (C_{gs}\ 300\ \mu m\ \text{FET}) \qquad (1)$$

$$R_{ds} = \frac{300}{w_g} \times (R_{ds}\ \text{of}\ 300\ \mu m\ \text{FET}) \qquad (2)$$

To ensure highly cascadable, unconditionally stable design a shunt RC feedback element was introduced into the design. Input and output matching of the MMIC FET device were realised by appropriate LC resonance networks. In the analyses gain was traded off for increased bandwidth hence reducing the susceptibility of the design to parameter variations due to modelling inaccuracies and component tolerances. The MMIC layout and the corresponding circuit diagrams are shown in Figure 2.

The manufactured MMIC amplifiers were tested as single stages prior to cascading. Under dc bias of V_{ds} = 5V and I_{ds} = 40mA the stage exhibited an RF gain of 10.5 dB and a noise figure of 2.8 dB. Under the optimum bias condition an additional 0.5 dB improvement in noise figure was recorded. The NF and Gain characteristics of the MMIC stage over range are shown in Figure 3 (a) and (b). The summary of the test data is shown in Table 1.

DC BIAS		V_{ds} = 5V, I_{ds} = 40mA	V_{ds} = 3V, I_{ds} = 20mA
Gain	(dB)	10.6	10
NF	(dB)	2.8	2.4
P1 dB	(dBm)	15	12
Input Match	(dB)	>15	>15
Output Match	(dB)	>15	>15

Table 1 : MIMIC Amplifier Characteristics

4. THE RECEIVER FRONT-END

The developed receiver front-end comprised MIC LNA stage and MMIC gain block. The latter is constructed of three MMIC amplifier stages in cascade giving a total gain of 30.5 dB. Over a 160 MHz bandwidth the NF, input and output match are 2.9 dB, 16 dB and 15 dB respectively. The gain and NF performance of the developed light weight L-band front-end module are shown in Figure 4. The performance of the module over the band of 1.56 GHz to 1.62 GHz is summarised in Table 2.

Gain	45 dB
NF	0.7 dB
Output VSWR	18 dB
Input VSWR	15 dB
P 1 dB	12 dBm
DC Power (V_{ds} = 3V)	360 mW

Table 2 : Receiver Front-End Module Performance Summary

5. CONCLUSIONS

This work has successfully demonstrated development of L-band receiver front-end based on a hybrid of MIC and MMIC technologies. The developed hardware exhibits the benefits of the miniaturisation of MMIC, technology, coupled with the inherent performance advantages of the front-end MIC technology. The result is an advanced technology L-band receiver ideal for applications in mobile and satellite communications. The achievement of a high performance in a miniaturised size fulfils the most stringent L-band receiver specifications.

6. REFERENCES

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(2) E. Bayar
Advances in Design of L-Band Lightweight Receiver for Phase Array Applications.
4th International Conference for Mobile Communications and Navigation, October 1988.

(3) I. D. Robertson and A. H. Aghvami
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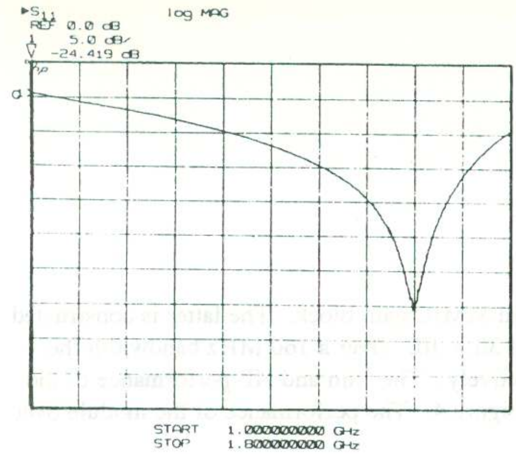
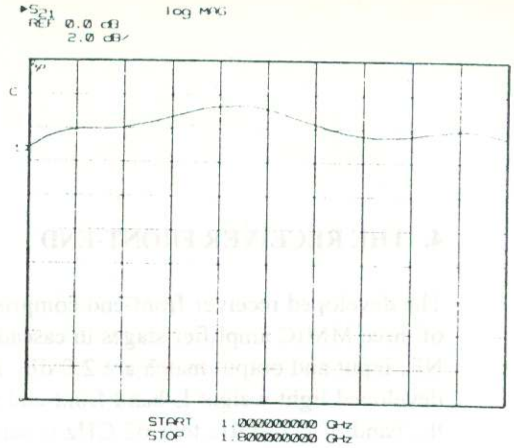
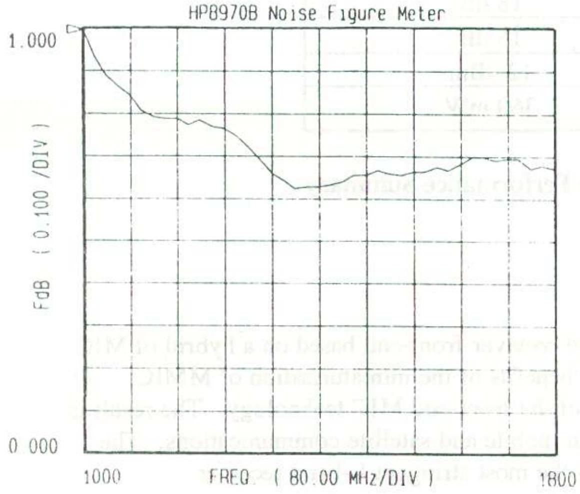


c) Input Match vs. Frequency

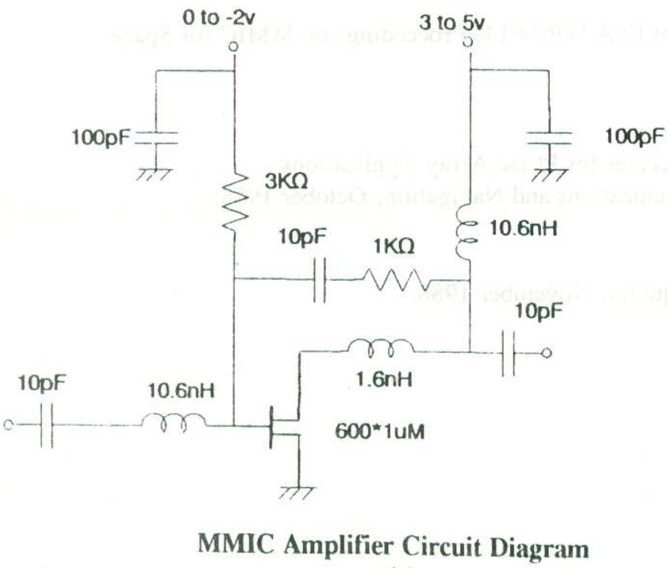


a) Gain vs. Frequency

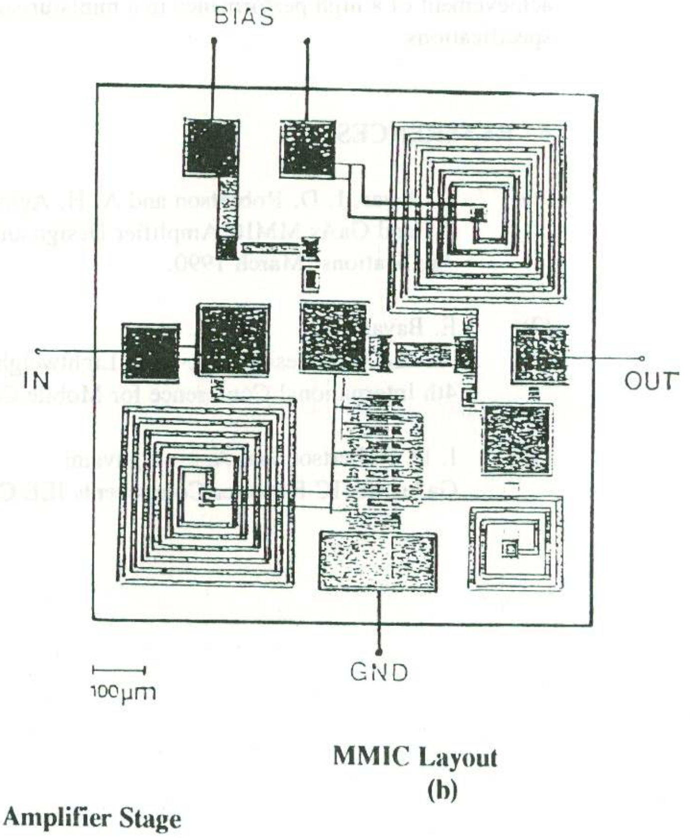


b) NF vs. Frequency

Figure 1 : MIC LNA Stage Performance

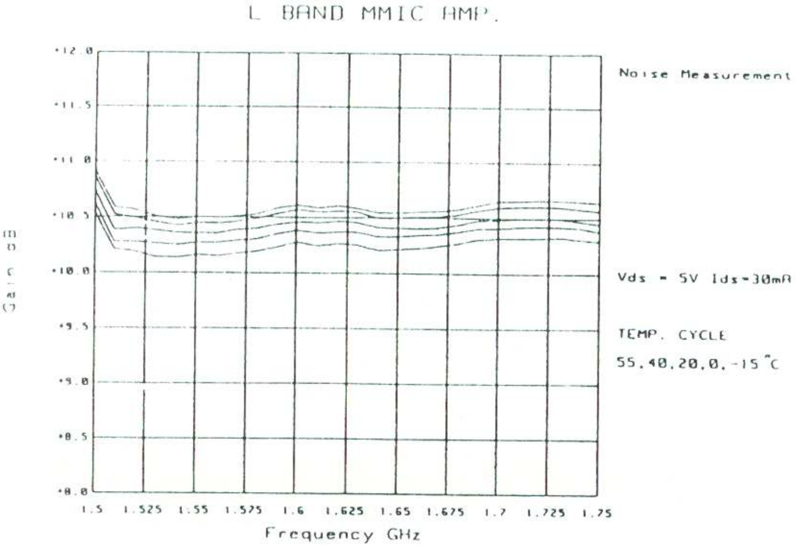


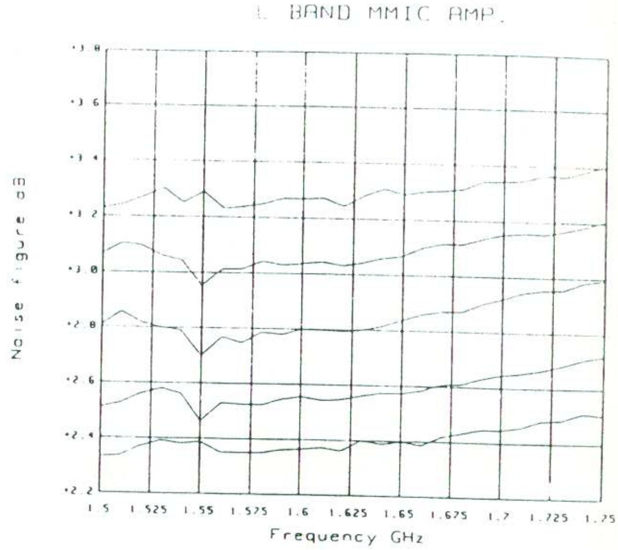
MMIC Amplifier Circuit Diagram
(a)



MMIC Layout
(b)

Figure 2 : MMIC Amplifier Stage

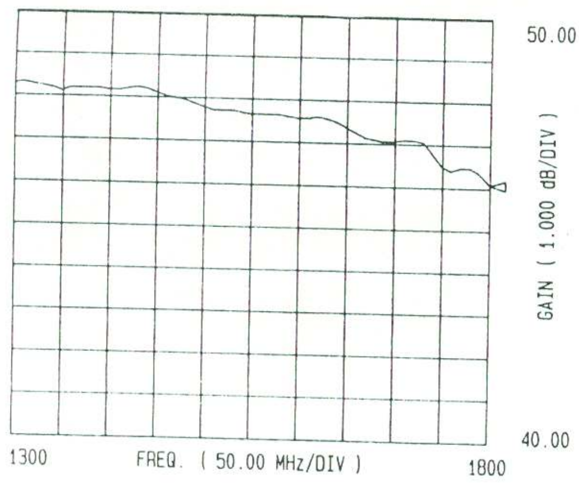


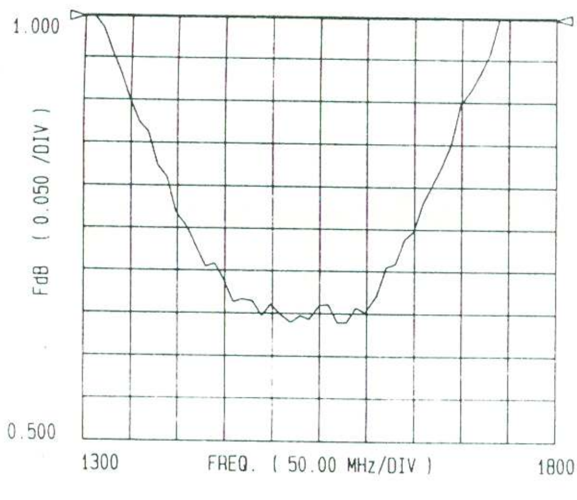


Gain versus frequency over temperature
(a)

NF versus frequency over temperature
(b)

Figure 3 : MMIC Stage NF and Gain Characteristics at +55, +40, +20, 0 and -15°C





Gain over frequency
(a)

NF over frequency
(b)

Figure 4 : L-Band Receiver Front-End RF Performance