Q-BAND COPLANAR WAVEGUIDE AMPLIFIER

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ABSTRACT

Q-band monolithic amplifiers using CPW (coplanar waveguide), GCPW (grounded coplanar waveguide), and MS (microstrip) structures were designed and RF evaluated. At 44 GHz, the CPW amplifier exhibited a gain of 7.5 dB and for the GCPW amplifier,the gain is 7.0 dB. These results compare very favorably with the MS amplifier which has a gain of about 7.5 dB. This represents the first reported Q-band monolithic amplifier using CPW structure. These results are encouraging and show great promise of future Millimeter-wave MMIC implementation using this structure.

I. INTRODUCTION

Recently there has been a growing interest in MMIC design employing CPW structure [1-3]. CPW structure has following advantages:

1)The ground plane is on the top surface,thus eliminates the need of via holes. This improves the gain performance of common source FET and makes the shunt connection of circuit elements easy.
2) Realization of balanced circuits are easier in a CPW/slotline enviroment than in microstrip.
3) Ground planes between lines provide good isolation property. This allows compact layouts.

However, CPW structure also has some disadvantages : it has higher conductive losses than microstrip for the same conductor width; there is scant of design information especially at millimeter-wave frequencies.

This paper describes the design of one-stage CPW MMIC amplifiers operate at Q-band.In order to study the third ground conductor effects, amplifiers were fabricated with and without the third ground conductor. To gain further insight into the potential advantages and worthiness of the CPW amplifier,its results were compared to a one stage microstrip MMIC amplifier which was designed and fabricated concurrently as the CPW amplifier. Finally, we report the design of a Q-band CPW-to-waveguide transition. This transition is designed to be compatible with CPW MMIC amplifier.

II. CPW MMIC AMPLIFIER DESIGN

The MMIC amplifier is based on a 4 mils thick semi-insulating GaAs substrate. The circuit topology is of a quasi-lowpass type,i.e.,only series transmission line matching elements are used. To further simplify the circuit implementation, only two impedance levels were choosen: 35 and 85 ohms. Impedance level less than 35 ohms is not used for they require prohibitively narrow gap between the center conductor and the two top ground plates; conversly,impedances higher than 85 ohms were not considered, this is to avoid the high conductive losses associated with the narrow center conductor and to maintain good equal potentiality of the two ground plates by keeping the distance between the two plates small. The circuit schematic of the complete amplifier is shown in Fig.1. The circuit performance was simulated using Touchstone [4]. To compensate for the step discontinuity, we applied a simple coutour compensation as suggested by Hoefer [5]. For CPW circuit, this compensation is needed for both center and ground conductors.

A photo of the complete amplifier is shown in Fig.2. The device is a 0.2 x 60 um AlGaAs/GaAs HEMT device. To suppress the slot line modes and to maintain equal potential between two ground conductors, air-bridges are placed at all step discontinuities and selective locations along the long transmision line. Input and output interfaces of the amplifier were designed to be compatible with Cascade Microtech's on-wafer probe heads.The chip measured 3.3 mm x 1.34 mm. The exclusive usage of straight transmission lines has contributed to this large size, significant size reduction can be achieved by meandered the line or by choosing other circuit topology, e.g., bandpass structure which consists of both series and shunt circuit elements. Finally it is

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worthwhile to mention that there are no via holes needed in this design.

III. MS MMIC AMPLIFIER DESIGN

The circuit topology for this amplifier is same as that of the CPW amplifier, that is, it also has a quasi-lowpass circuit structure. The difference is that, in this case, we have included bias networks in the design. Figure 3 and 4 show the circuit schematic and a photo of this amplifier. The measured die size is 1.9mm x 1.34mm. For easy characterization, amplifier's input and output interfaces also have been designed to be compatible with Cascade 's wafer probes.

IV. AMPLIFIER RF EVALUATION

Amplifiers' RF evaluation were done on wafer using Cascade Microtech's 50 GHz wafer probe in conjunction with a HP 8510A network analyzer with Q-band frequency extention unit. The on-wafer calibration is a standard "OPEN", "SHORT" and "LOAD" type calibration. To bias these circuits, external bias tees were used. These bias tees were connected right next to the probe heads. For CPW amplifier testing, the amplifier die was placed on-top of a 25 mils thick Al_2O_3 substrate to assure an ideal CPW enviroment.

All amplifiers were biased for optimum gain operation. Figure 5 to 7 shows the gain and input return loss performances for all three amplifiers. At 44 GHz, for the CPW amplifier, it has a gain of 7.5 dB and an input return loss about 10 dB; for the GCPW amplifier, it has a gain of 7 dB and an input return loss also about 10 dB; for the MS amplifier, it exhibited about 7.5 dB gain and > 12 dB input return loss. From these figures, it is clearly seen that both CPW and GCPW amplifiers demonstrate well-behaved gain reponses and rugged input return losses; on the contrary, the MS amplifier displayed a zigzagged gain reponse (the gain ripple is more than 2 dB), and a fairly well-behaved input return loss. It is very interesting to notice that, even with a thin 4 mils substrate, the behaviors for CPW and GCPW are almost non-distinguishable , except for the slight frequency shift of the input return loss of the later.

V. WAVEGUIDE TO CPW TRANSITION DESIGN

A Q-band waveguide-to-CPW probe transition was designed. This design is similiar to the waveguide-to-microstrip transition reported earlier [6]. A E-probe is used to couple power from waveguide to CPW transmission line. The design is based upon a 5 mils Al_2O_3 substrate. Figure 8 and 9 show a photo and the performances of this transition. From 43 to 50 GHz, this transition exhibited a insertion loss less than 2 dB and a return loss about 15 dB. Notice that the center section of this transition is physically compatible with the CPW MMIC.

VI. SUMMARY

We have reported the design and performances of CPW-based MMIC amplifiers operate at Q-band. Both CPW and GCPW amplifiers were evaluated. Their performances show little distinction. Both results compare very favorably with a microstrip MMIC amplifier. These results are very encouraging and show great promise of future millimeter-wave receiver development using this structure.

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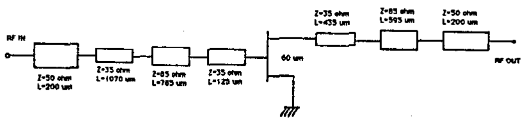

Fig. 1 Circuit schematic of Q-band CPW amp.

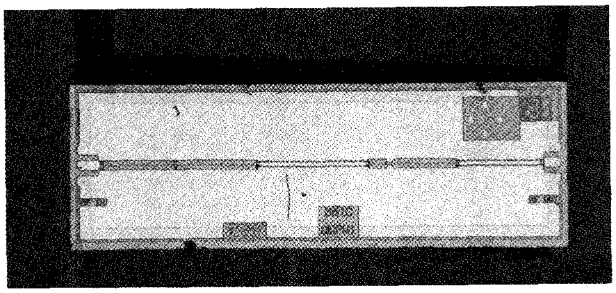

Fig. 2 Photograph of Q-band CPW amp.

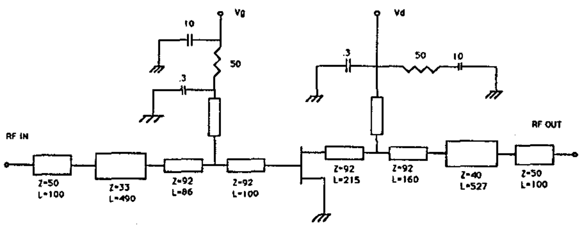

Fig. 3 Circuit schematic of Q-band MS amp.

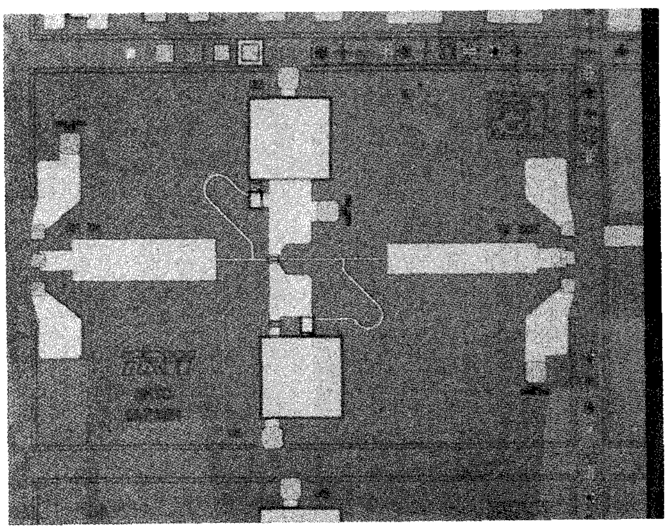

Fig. 4 Photograph of Q-band MS amp.

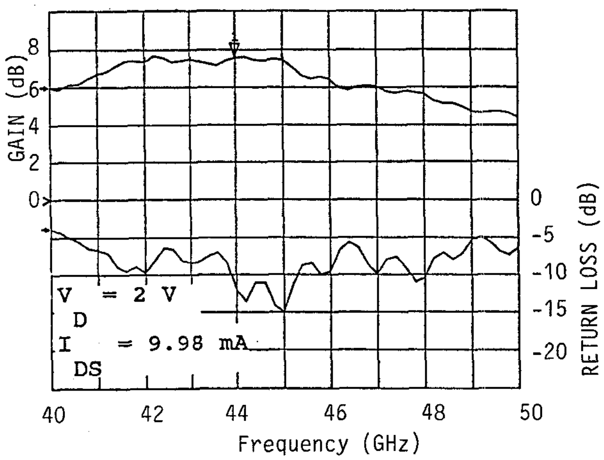

Fig. 5 Performance of Q-band CPW amp.

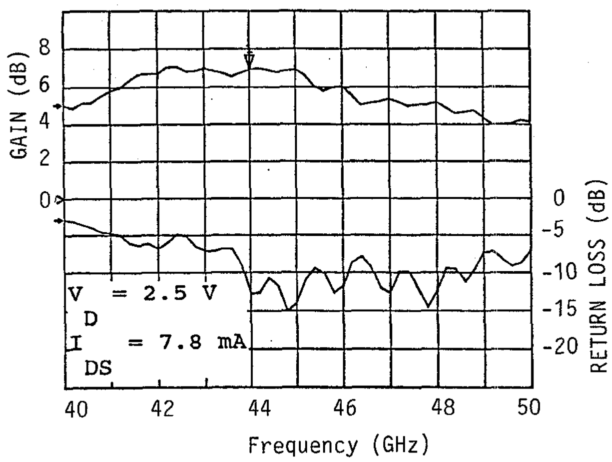

Fig. 6 Performance of Q-band GCPW amp.

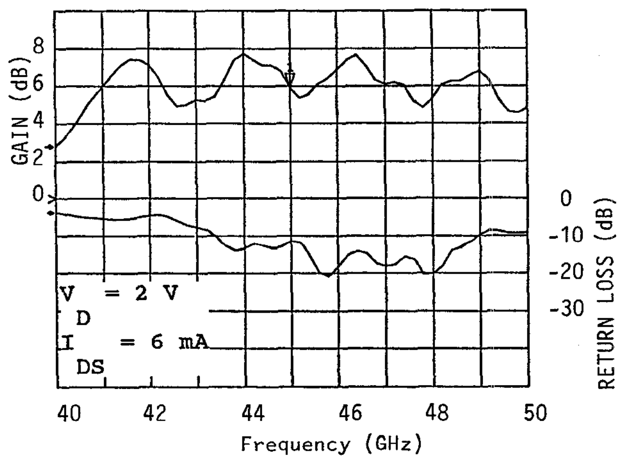

Fig. 7 Performance of Q-band MS amp.

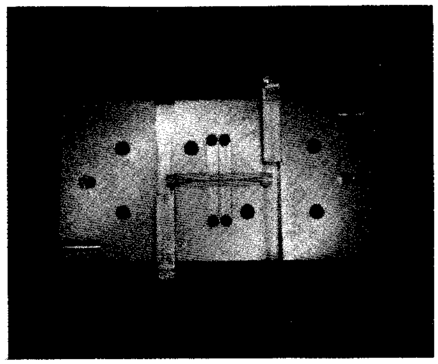

Fig. 8 Photograph of Q-band CPW-to-WG transition.

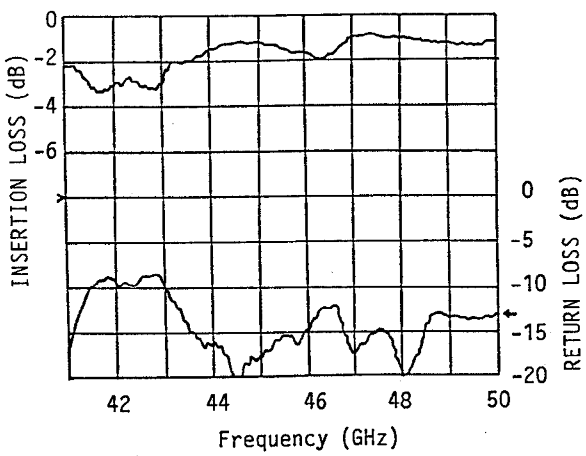

Fig. 9 Performance of waveguide-to-CPW transition.