FULL-WAVEGUIDE BAND, 90 TO 140 GHZ, MMIC AMPLIFIER MODULE

S. Weinreb[1], P.C. Chao[2], and W. Copp[2]
[1] U. of Massachusetts, 619 Lederle GRC, Amherst, MA, 01003
[2] Lockheed Sanders, 65 Spitbrook, Nashua, NH, 03060

ABSTRACT

A six-stage, indium phosphide, monolithic integrated circuit amplifier has been fabricated and tested in a WR-8 waveguide mount. The amplifier has a gain of 15 +/-3 dB in the frequency range of 90 to 140 GHz and a noise figure of 7.0 dB at 110 GHz.

INTRODUCTION

The frequency range above 110 GHz is rich for monitoring of the atmosphere through molecular lines of oxygen at 118 GHz (used to measure temperature vs height), water at 183 GHz (humidity vs height), and many other trace chemicals which are important for studies of ozone depletion and pollution control. This frequency range also has potential for very wideband, local-area communication links where the attenuation vs frequency characteristics of the atmosphere can be used to control interference. The performance and cost of receivers in this range can be greatly improved with integrated circuit (MMIC) low-noise amplifiers utilizing InP based high-electron mobility transistors (HEMTs). Two recent reviews of the development of these transistors have been presented by Mishra and Shealy [1] and Smith [2]. Two-stage MMIC amplifiers with 10 to 12 dB gain in the 119-123 GHz range [Lai, et al, 3] and 6 to 9 dB gain in the 138-144 GHz range [Wang, et al 4] have been reported; both of these gain results are referred to the chip terminals with 2 dB of waveguide fixture loss not included.

DESCRIPTION

This paper describes a 6-stage MMIC amplifier module utilizing 0.1 x 36 µm InAlAs/InGaAs HEMTs on a 50 µm thick InP substrate and providing 15 +/- 3 dB waveguide-to-waveguide gain over the entire WR-8, 90 to 140 GHz range. The amplifier utilizes coplanar-waveguide (CPW) transmission lines with via-holes to prevent microstrip mode excitation. The chip size is 640 x 2250 x 50 µm and the layout is shown in Figure 1. The transistors used in the MMIC are described in a previous article [5] except that no passivation was applied in this first design iteration.

The MMICs were first DC tested and 8 out of 10 samples were DC good with typical peak DC extrinsic transconductance of 22 mS (611 mS/mm) at Vd = 1.0 V, Id = 5 mA per transistor, and Vg = -0.1 V. Two of these were then mounted in WR-8 waveguide blocks which can function as test fixtures or prototype system amplifiers. The waveguide block, shown in Figure 2, is split along the waveguide broad wall and utilizes E-plane probe transitions fabricated from 125 µm thick Rogers Duroid 5880 laminate ($\epsilon_r = 2.20$). The transition loss was not measured but calculated values including waveguide loss is approximately 0.4 dB per transition.

RESULTS

The gain, input return loss, and output return loss of the MMIC modules were measured with a scaler network analyzer. Two signal sources were utilized. One covered 79 to 114 GHz, utilizing a HP8350 13.17 to 19 GHz source driving an Avantek active doubler driving a Millitech MUT10 tripler. The second source covered 107 to 142 GHz and utilized the HP8350 source at 8.92 to 11.83 GHz driving a DBS active quadrupler driving a Millitech FTT-06 tripler. Cutoff waveguides were used to suppress spurious lower harmonics.

The measured gain and NF vs frequency for one module is shown in Figure 3. The waveguide input-to-output gain is 15 +/- 3 dB from 87 to 140 GHz. This is a usable gain over a very wide bandwidth (full WR-8 waveguide band) but is approximately 12 dB less than the design gain. The discrepancy is explained by the somewhat low transconductance of this particular wafer. A transconductance 2 dB higher in each of the 6 stages (i.e. 769 mS/mm instead of 611 mS/mm) would increase the gain by 12 dB. This transistor process has previously given 1000 mS/mm [5].

Two waveguide modules were cascaded to give 25 +/-8 dB gain over the 107 to 140 GHz range (not measured at lower frequencies) and the noise figure of this cascade was measured at several points in the 110 to 120 GHz range with results of 7.0 to 8.5 dB (1168K to 1764K). The noise figure was measured utilizing 300K and 77K absorber material (dipped in LN2), a feed horn, the cascaded amplifier blocks, and a waveguide second harmonic mixer. The results include losses in the waveguide transition and are corrected for 0.5 dB of loss in 50 mm of WR-8 waveguide to the feed horn and for a second stage contribution of 0.2 to 0. 0.8 dB dependant upon frequency.

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The amplifier was designed with MMICAD using models of a transistor different from that actually used in the MMIC. Higher, more uniform, gain and lower noise is expected from revised designs using more accurate models and higher transconductance transistors..

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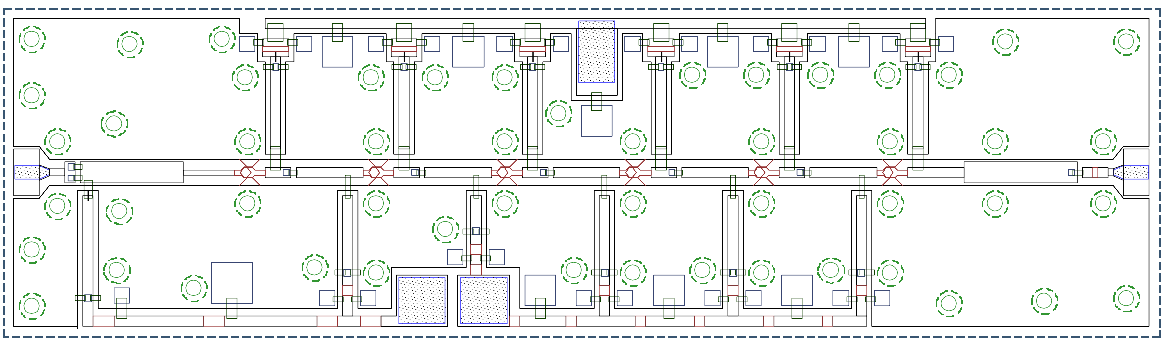

Figure 1 - Layout of 90 to 140 GHz 6-stage amplifier with chip size 2250 x 640 x 50 µm.

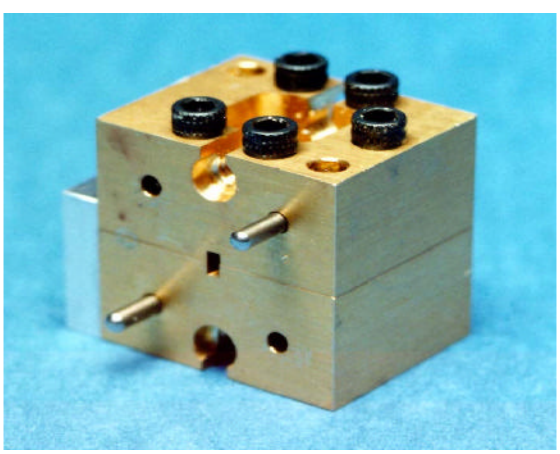

Figure 2 - Photograph of WR-8 amplifier module with size 19 x 19 x 15.2 mm. Input and output are in-line with internal E-plane 90° bends coupling to microstrip probes.

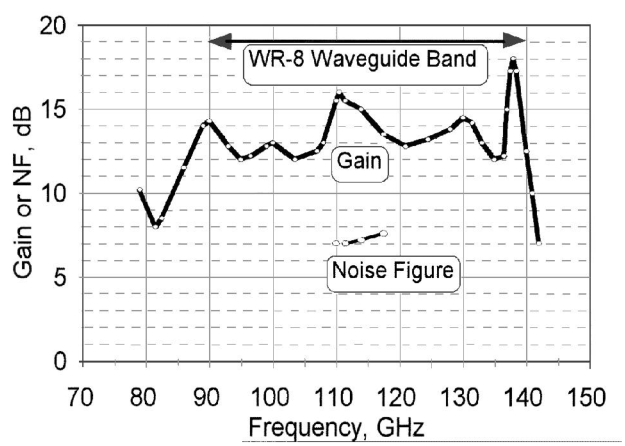

Figure 3 - Measured gain and noise-figure of the amplifier module.