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COPLANAR WAVEGUIDES USED IN 2–18 GHz DISTRIBUTED AMPLIFIER

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ABSTRACT

This paper describes the use of coplanar waveguide as an alternative transmission medium in a monolithic distributed amplifier. The coplanar waveguide layout substantially reduces coupling effects between adjacent lines, and eliminates the need for via holes and substrate thinning, leading to higher fabrication yields. The resulting device reported here is a compact ($1.3 \times 1.5mm$) low noise distributed amplifier on a thick GaAs substrate (15 mil), with a gain of $6.0 \pm 0.5dB$ over the frequency range of $2 - 18GHz$.

INTRODUCTION

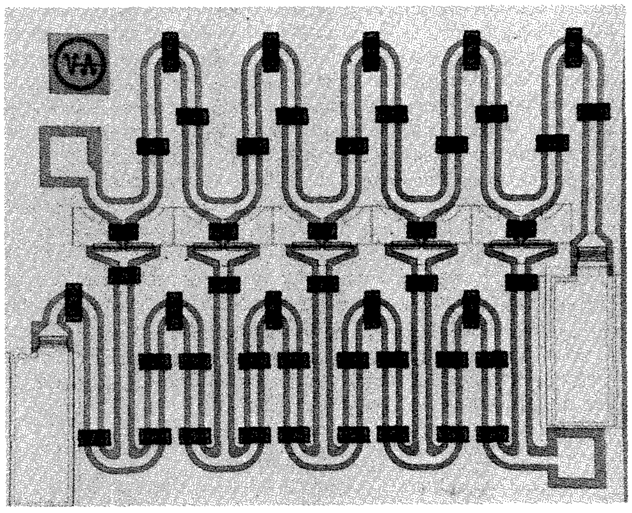
Coplanar waveguides offer two main advantages over microstrip lines in the design of distributed amplifiers. (I) The source groundings of the active devices are done easily without the use of via holes. This allows for thick substrates offering easier handling and reduced number of processing steps, leading to increased yield. (II) Since a ground plane exists between any two adjacent transmission lines, coupling problems are reduced resulting in potentially more compact desings.

It is necessary when using coplanar waveguides to avoid multimode propagation along the line. The preferred mode of operation is the "odd"[1] mode which is quasi TEM. The "even" non TEM mode is a slotline mode and needs to be suppressed. A simple method for suppressing the even mode, as well as connecting all the grounded regions, is the introduction of airbridges across the line, connecting the ground planes on both sides of the center conductor. This will effectively increase the cutoff frequency of the slotline modes, leading to single mode operation.

Another problem in designing coplanar circuits is the lack of CAD optimization programs for them. However, if in the design of an amplifier small uncertainties in the value of the effective dielectric constant have minor effects on the overall performance, it is possible to optimize the initial circuit assuming microstrip transmission lines, and add any necessary line length adjustments after the effects of propagation constant variations have been studied separately. Line discontinuities can also be constructed individually for measurement modeling, and consequent incorporation in the circuit.

CIRCUIT DESIGN

Two different design approaches were taken. In the first approach five FETs of equal gate widths were used with a total periphery of 750 μm (Figure 1). The FETs have a nominal gate length of $0.5\mu m$ defined by optical lithography. The gate and drain lines were chosen to be identical, giving minimum sensitivity to parameter variations. Sharp corners were avoided by smooth bending of the lines. Two versions of this design with and without terminations were fabricated. The device without terminations was used to study the line loss as a function of bias voltages.



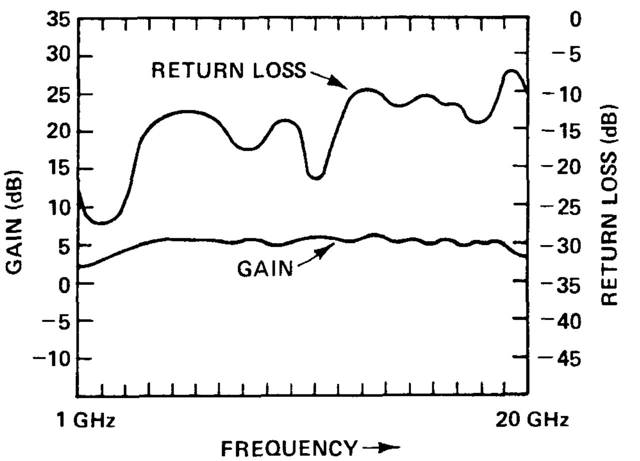


Figure 1. Uniform FET width distributed amplifier, and the corresponding measured values of gain and return loss.

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The second approach involved using variable gate widths to achieve better low pass filter characteristics for the lines (Figure 2). Five FETs were used in the design with a total periphery of 720 μm. The uniform width amplifier is smaller in size with dimensions of $(1.3 \times 1.5 mm)$. The variable width amplifier is $(1.9 \times 1.9 mm)$.

A wafer was prepared containing passive coplanar elements for verification of models and loss analysis. As expected[2], coplanar lines were found to be in general lossier than microstrip lines of the same impedance. This difference is particularly noticable for thin metalization on the lines ($\approx$ 1000 Å) where the coplanar line could be as much as 1.0 dB/in. lossier. With thick metalization ($\approx 2 \mu m$) The difference becomes less pronounced. At 18 GHz, the line loss for the coplanar meanderline used in the distributed amplifier was found to be approximately 1 dB/in., which is very close to what was measured for a similar microstrip line.

EXPERIMENTAL RESULTS

Amplifiers were fabricated on ion implanted, Molecular Beam Epitaxial (MBE), and Organo-Metallic Chemical Vapor Deposition (OMCVD) material. Devices with lower current consumption and better overall performance were obtained on OMCVD and MBE wafers. Figure 1 shows the gain and return loss of the uniform gate width amplifier. Slightly higher gain was observed for the variable gate width device at the expense of larger overall size (Figure 2). These measurements were made on the uncleaved wafer using a Cascade probe station.

In testing the same amplifiers using microstrip fixtures, it was found that the involved transition between microstrip and coplanar lines seriously degrades the amplifier performance above 8 GHz. This is due to insufficient grounding caused by bond wire inductance connecting the two ground planes. This fact was verified using electro-optic sampling of the amplifier's ground potential[3], which showed considerable fluctuations above 8 GHz.* Considerable performance improvement resulted from mounting the amplifiers in coplanar fixtures.

CONCLUSION

It was shown that coplanar waveguides can be used as the transmission medium in distributed amplifiers, offering the advantage of increased yield without sacrificing device performance or size.

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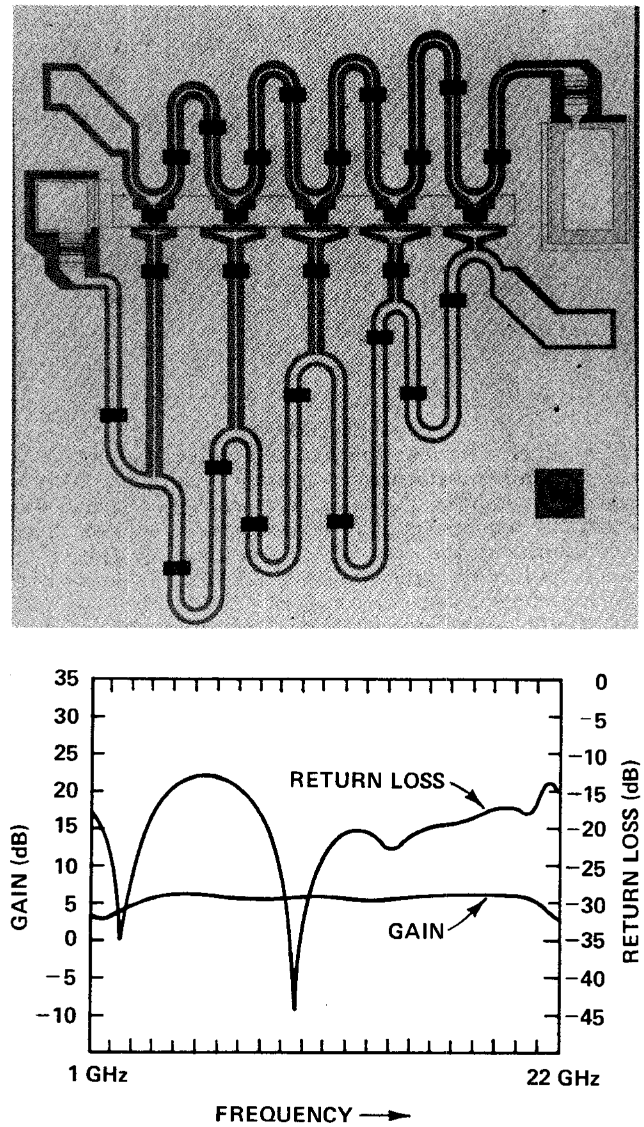

Figure 2. Variable FET width distributed amplifier, and its measured gain and return loss as a function of frequency.

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* In fact it can be shown that with insufficient grounding a third propagation mode can exist on the coplanar line. This could be partially responsible for the degraded performance observed.[4]