LOW NOISE WIDEBAND FIBEROPTIC MMIC-BASED RECEIVER

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Abstract

A low noise wideband fiberoptic MMIC-based receiver consisting of a two-stage feedback amplifier with minimum gain of 10 dB and 5 dB maximum noise figure from 6 to 15 GHz is presented. This bandwidth and noise performance represents a significant improvement over available hybrid designs. The receiver is usable up to 17 GHz. The improved RF performance is obtained by flip-chip mounting a photodiode onto the MMIC chip which minimizes the parasitics, extending bandwidth and improving noise.

Introduction

The receiver described in this paper consists of a photodiode flip-chip mounted on a MMIC amplifier which incorporates a reactive input matching network. This design is considerably better than a conventional optoelectronic receiver where the photodiode is normally resistively matched to 50 Ω and usually results in 6 dB matching loss and a similar degradation in system noise figure.

Circuit Design

The MMIC amplifier was designed according to the design rules provided by TriQuint Semiconductor using their HA™ Process. The feedback amplifier design was chosen for its good VSWR and bandwidth, ability to be cascaded and process tolerance. A 0.5 μm gate length and 300 μm gate width FET was used. The circuit model, S-parameters and noise parameters for the devices were provided by TriQuint Semiconductor, Inc.

The amplifier was designed by optimizing the feedback for best gain, gain flatness and VSWR[1]. The resulting feedback stage was then reactively matched to the photodiode. A model of the photodiode was generated from measured input reflection coefficient (S_{11}) of the photodiode, in order to design the matching network. Figure 1 shows the resulting lumped element equivalent circuit of the photodiode[2]. Figure 2 demonstrates the overall block diagram of the optical receiver, including the photodiode, 2-stage amplifier and all the interstage matching networks.

The S_{11} of the photodiode was transformed to lie on the constant gain circles in the input reflection coefficient plane of the feedback amplifier constructed earlier. Then the output constant gain circle of this network (photodiode plus one amplifier) was adjusted to lie on the output gain circles of a single feedback amplifier, for best gain flatness across the frequency band[2]. Finally, the output of this network was matched to 50 ohm termination. Wider bandwidth and flatter gain response was achieved by "fine tuning" the models of the feedback amplifier and the matching networks in Touchstone™.

Figure 3 displays the final schematic of the optical/microwave receiver. Tuning of the amplifier was accomplished by breaking selected airbridges. Airbridges were used to short out small loops of transmission lines.

Fabrication & Test

After fabrication, the MMIC amplifier chip was separately assembled and characterized before combining with the photodiode. This was accomplished by directly providing an RF input to the MMIC chip. See Figure 4 for the measured gain of the MMIC amplifier. The response began to roll-off near 16 GHz due to parasitic elements of the FETs and to imperfect input impedance matching to the amplifier.

After separately fabricating the InP-based photodiode chip and GaAs MMIC amplifier, the photodiode was flip chip mounted on the MMIC and the receiver module was assembled[3]. An angle polished fiber was used to bring light onto the back side of the photodiode chip[4], allowing the photodiode/MMIC chip, substrates and optical fiber to be in a single plane. This was necessary to permit room for internal probing and optical/microwave testing of the packaged MMIC chip. Figure 5 schematically shows the angled fiber attachment.

Performance

Figure 6 displays the frequency response of the receiver. The response was limited at high frequencies by the MMIC amplifier. Figure 7 is a plot of the device output VSWR. Figure 8 illustrates the noise figure of the receiver as a function frequency. The noise figure of our optical receiver is approximately 5 dB, which is much better than separate hybrid photodiode and amplifier modules used previously. A typical photodiode resistively matched to 50 Ω introduces 6 dB loss[5]. This photodiode in combination with a typical microwave amplifier of about 5 dB noise figure, results in approximately 11 dB equivalent noise figure.

Conclusion

An ultra low noise, high frequency fiberoptic MMIC-based receiver module with 5 dB Noise figure and a bandwidth of 6 to 15 GHz has been developed. It was shown how flip chip mounting can reduce parasitics and help achieve higher frequency performance. To improve the design, more accurate

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computer models (both noise and S-parameter) are needed for the FETs when connected to high-impedances such as photodiodes.

The design demonstrates the viability of using MMIC technology in conjunction with fiberoptics, in order to achieve low noise, high performance, microwave communications links.

Acknowledgement

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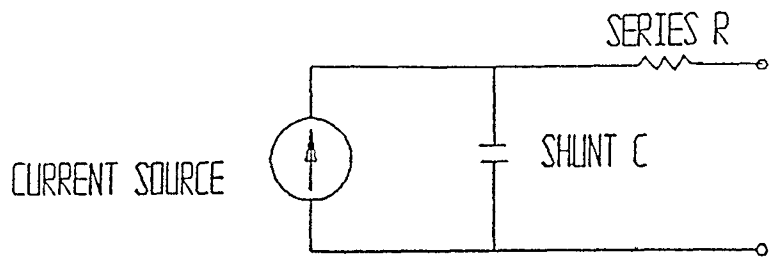

Figure 1. Equivalent circuit of photodiode. Capacitance is 90fF and resistance is 12 ohms.

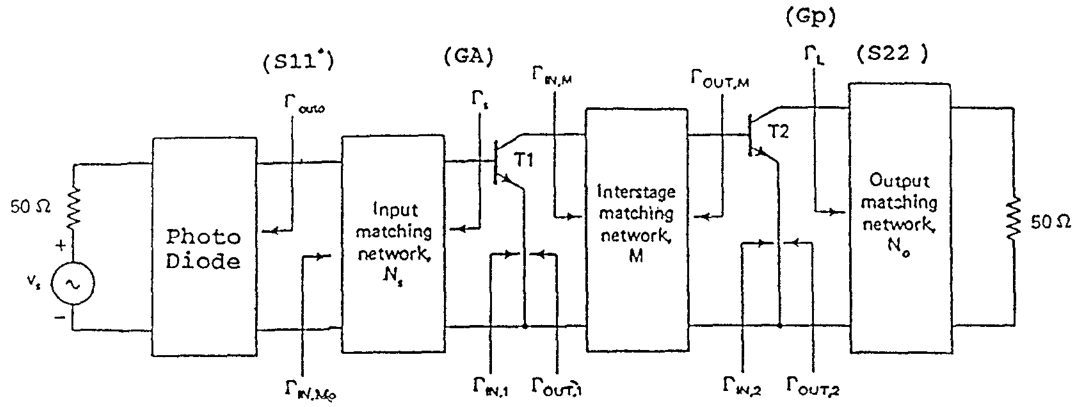

Figure 2. Block diagram of optical receiver, showing the photodiode, matching networks and amplifier stages.

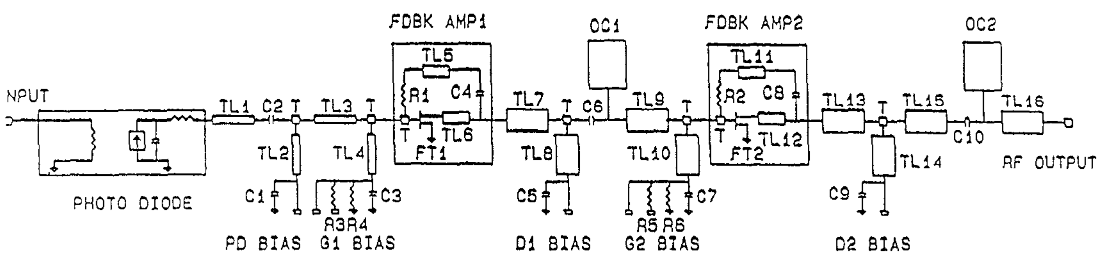

Figure 3. Circuit schematic of optical receiver.

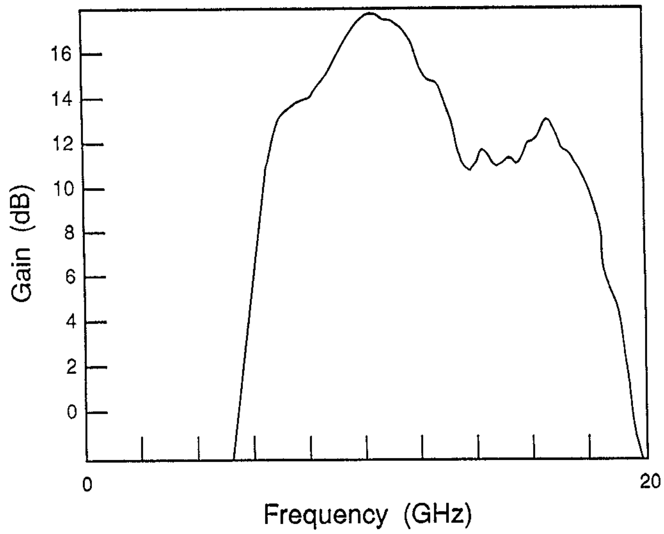

Figure 4. Measured gain of MMIC amplifier as a function of frequency.

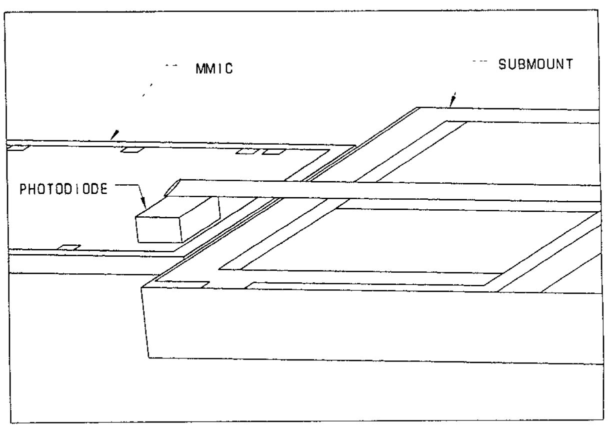

Figure 5. Fiber coupling assembly showing angled polished fiber coupling light into the photodiode chip.

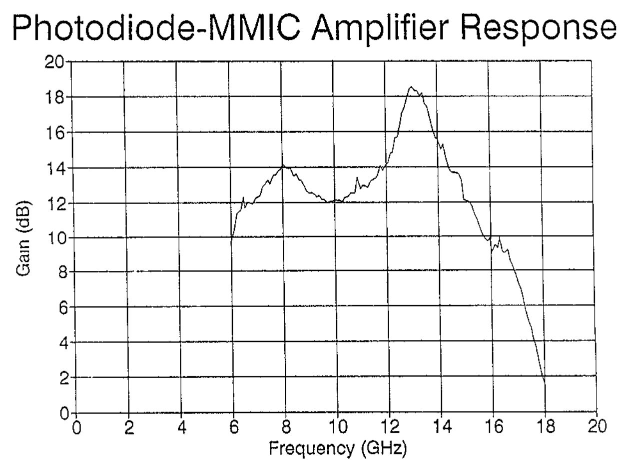

Figure 6. Frequency response of the optical receiver.

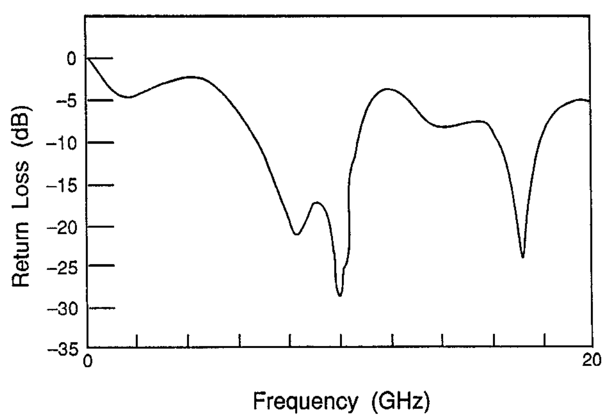

Figure 7. Return loss of optical receiver as a function of frequency.

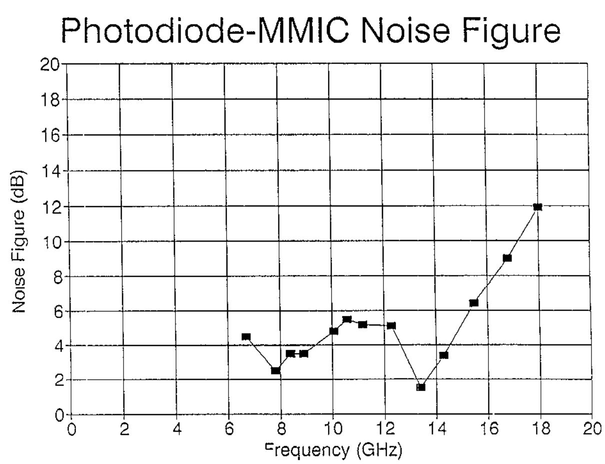

Figure 8. Noise figure of optical receiver as a function of frequency.