A WIDEBAND LOW NOISE GaAs HYBRID OPTICAL RECEIVER FOR A COHERENT FIBRE OPTIC COMMUNICATION SYSTEM

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ABSTRACT

A low noise GaAs hybrid front-end amplifier suitable for coherent optical links is described. The microwave characterisation and modelling of a low capacitance PIN photodiode is used in the design of a high impedance (integrating) receiver. A 5 GHz bandwidth, transimpedance gain of 430Ω and an equivalent input noise current spectral density of 6 pA/√Hz at the IF frequency of 1.2GHz is achieved.

INTRODUCTION

Coherent optical detection in fibre-optic transmission is emerging as a viable technology for high sensitivity and multi-channel links. In a coherent heterodyne system the input signal is mixed with a local oscillator (LO) to provide an intermediate frequency (IF), improving the gain and therefore sensitivity of the overall receiver. A low noise receiver is required to minimise the LO power required for shot noise limited operations and a wide bandwidth is required to accept the electrical IF generated by the signal and LO lasers. For operation at high data rates, and in the long wavelength transmission windows of optical fibre, the combination of a GaInAs PIN photodiode and GaAs FET front-end amplifier offers an excellent approach.

To make use of all the LO power in a coherent receiver balanced mixer techniques are employed (Ref 1). Combining of the signal and LO optical beams is accomplished in a four port optical device with the result that there are two optical outputs to be detected. An optical coherent receiver therefore employs two detectors, one at each of the output arms of the combining optics in order to maximise the detected signal power. The optimum split ratio is 50% so each photodetector receives half of the combined LO and signal power. Balancing of the detected photocurrents also permits suppression of the local oscillator intensity noise. The receiver described in this paper employs these principles.

Optical coherent multichannel systems have potential applications in broadband subscriber networks especially for distribution services. The extra sensitivity of coherent detection allows the transmitted signal to be split to more subscribers, each being able to tune into one of the many available channels. In order to select a channel a tunable LO laser is switched between many incoming transmitted signals which will be at random and time varying polarisation states. One method of dealing with the random polarisations is the technique called polarisation diversity. Both signal and LO are resolved into the TE and TM modes and separately combined using an electrically controlled lithium niobate chip before detection and mixing on the photodiodes (Figure 1). The receiver described is used as a polarisation diversity front-end, where a linear planar array of 4 photodetectors is designed to interface with a lithium niobate polarisation diversity chip (Ref 2). Two symmetrical receiver circuits are used to amplify the TE and TM modes separately before further signal processing.

RECEIVER DESIGN

For the microwave receiver design a bare chip and wire bond hybrid approach is taken using short gate length, low gate leakage GaAs MESFETs which minimise noise and input capacitance. The thin film circuit is constructed using an alumina substrate with interstage matching elements realised as microstrip transmission lines to maximise bandwidth (Ref 3).

In order to produce a high sensitivity receiver the contribution of Johnson noise sources at the input need to be minimised. A high impedance (integrating) front-end design is chosen for this reason. A large bias resistor at the input integrates the detector output over a large time constant formed by the input capacitance of the photodiode and resistance of the bias resistor. Internal equalisation at a later stage in the circuit restores flat gain over the band by performing the required differentiation. A circuit with an input resistance low enough for equalisation not to be needed would incur a severe noise penalty making the integrating front-end superior for wide bandwidth, low noise applications.

The circuit diagram is shown in Figure 2. Four a.c. coupled FET amplifiers biassed in a common source configuration provide the gain. The PIN diodes are low capacitance GaInAs photodiodes with a wavelength response covering 1.1 to 1.6 microns mounted on quartz to reduce parasitics and aid alignment. The hybrid circuit was fully simulated using the standard microwave software package Touchstone™ to predict transimpedance gain, bandwidth and equivalent input rms noise current density (Ref 4). Hybrid components were characterised and their equivalent circuits included in the simulation. An equivalent microwave model of the mounted photodiode, derived from a one port S-parameter measurement and bond wire inductances were also included.

RESULTS

The measured frequency response of the receiver is shown in Figure 3. It demonstrates a usable bandwidth of up to 5 GHz with a transimpedance gain of 430Ω. The noise spectral density in pA/√Hz up to 2GHz is shown in Figure 4. When used in a system designed to detect FSK modulated data at a rate of 280Mb/s the measured noise spectral density at the lower and upper sideband frequencies is 5 and 7pA/√Hz respectively.

CONCLUSIONS

A low noise 5GHz bandwidth dual detector optical receiver front-end module suitable for use in a coherent optical heterodyne receiver has been designed and realised and evaluated in fibre optic transmission links. The hybrid circuit uses discrete devices on an alumina substrate and is designed to minimise parasitics. The receiver has been assembled into a complete module which also includes an optical polarisation diversity circuit and interfaces to a pair of the dual detector receiver front-ends.

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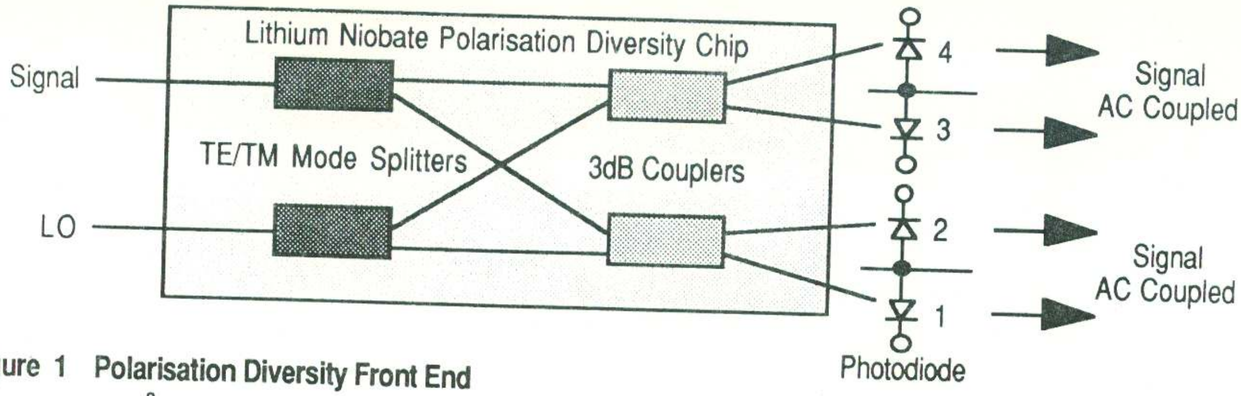

Figure 1 Polarisation Diversity Front End

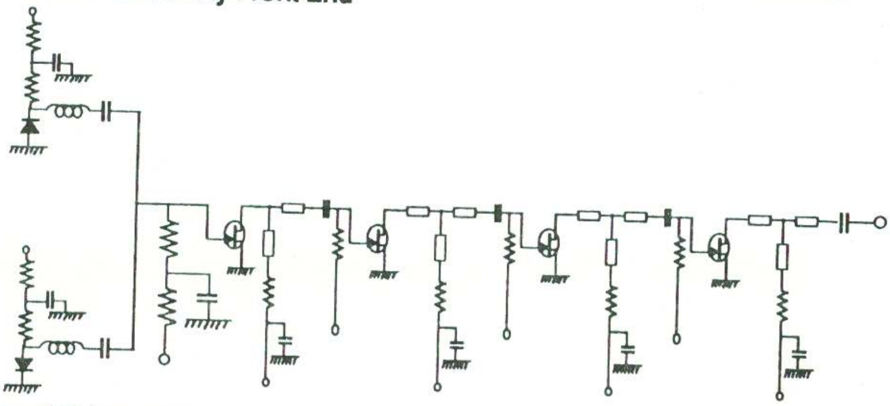

Figure 2 Circuit Schematic

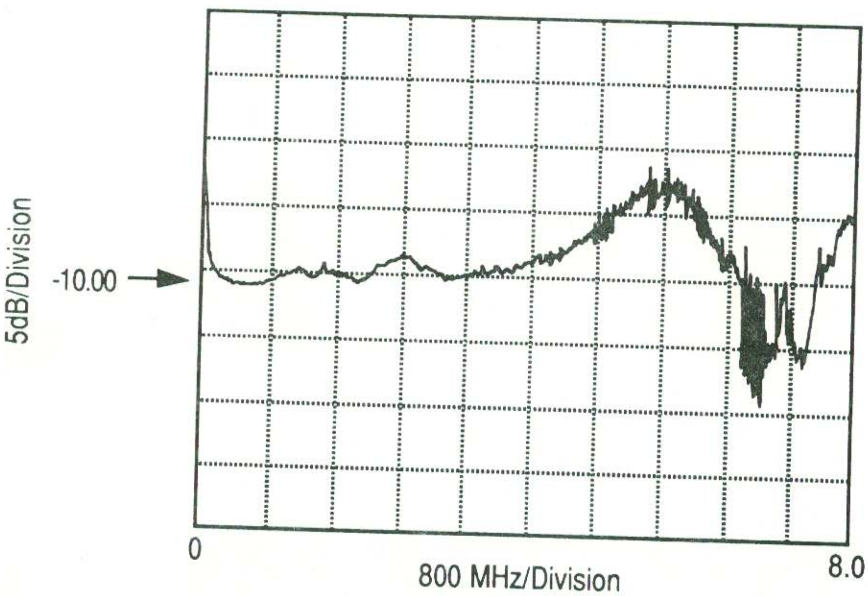

Figure 3 Frequency Response of Receiver

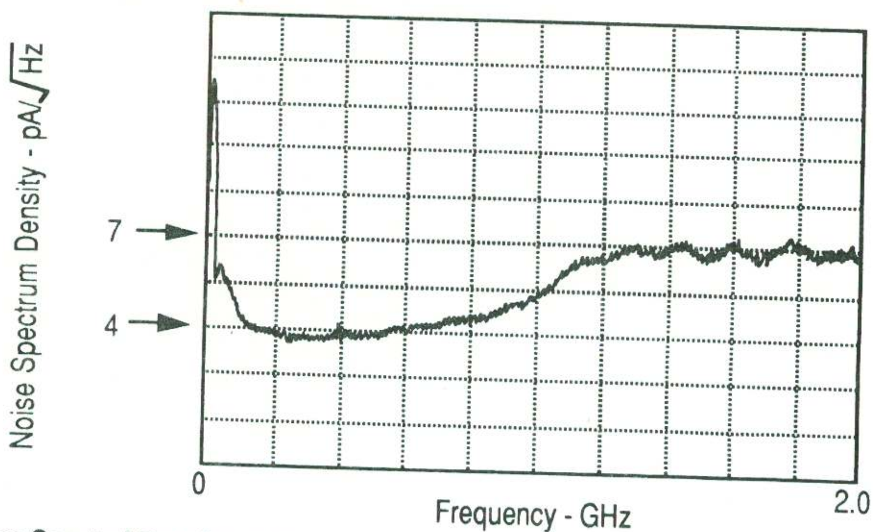

Figure 4 Noise Spectral Density of Receiver