We investigated the performance of the DPA experimentally by transmitting the packets through a laser, optical fibre, photodetector and demodulator. The BER of the DPA-recovered channel is shown in Fig. 3. The ideal curve has been measured by connecting the clock directly from the transmitter to the receiver, while the DPA BER has been measured with 1, 2 and 4 bit preamble lengths. Longer preambles have not been considered because of the increased complexity of the required logic and the small improvement over the 4 bit preamble (see Fig. 2).

Our theoretical analysis and experimental measurements suggest the following conclusions: (i) the prototype performance agrees very well with the calculation (compare Fig. 3 with Fig. 2); (ii) the 4 bit DPA has only 1dB penalty as against the ideal receiver, and the 2 bit DPA has only 0.8dB additional penalty; (iii) the DPA performs a clock acquisition from scratch in 50ns (four preamble bits) or 25ns (two preamble bits), outperforming all other clock recovery devices. The better performance of the 4 bit DPA over the 2 bit is due to the fact that it averages over four preamble bits instead of two, thereby reducing the effect of noise and jitter.

The bit rate of our current prototype is limited by the availability of components (high-resolution delay lines and fast programmable logic devices) and metastability. A much faster fully-custom designed single-chip CMOS implementation of the DPA using 64 preamble bits for 2.5Gb/s bit streams is currently being developed.

Summary: We have proposed and implemented an ultrafast clock recovery technique that locks within four preamble bits at 80Mb/s with 1dB penalty versus an ideal clock recovery. This scheme is very useful for ultrafast clock recovery in high-speed optical packet-switched networks.

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References


**Introduction**: Various optical receivers based on pin photodiodes have been reported for 10Gbit/s optical transmission [1 – 3]. The best reported sensitivity of –29.4dBm was obtained for a pin-HEMT optical receiver [2]. Recently, a pin-HEMT optical receiver employing a noise matching network based on the noise figure concept was reported, which had an ultralow noise performance up to a predicted sensitivity of –22.5dBm [4]. The reported pin-FET hybrids employed high impedance circuit designs. The reason for implementing high impedance pin-FET receivers is to reduce the circuit noise for high sensitivity in spite of narrow dynamic range. From the standpoint of system applications, the transimpedance optical receiver is preferred owing to its inherent wide dynamic range performance. A recent pin-HEMT 10Gbit/s receiver design predicts that an ultralow noise performance and a wide dynamic range can be obtained [5]. We report a 10Gbit/s pin-HEMT receiver simultaneously having high sensitivity and a wide dynamic range by employing a lossless noise matching network and a transimpedance type amplifying stage. A measured sensitivity of –23.5dBm and a dynamic range of 23.5dB are obtained, which are the best results reported at 10Gbit/s for a pin-HEMT receiver to date.

**Fig. 1** Schematic diagram of lossless tuned and transimpedance pin-HEMT optical receiver

**Description**: The schematic diagram of the receiver is shown in Fig. 1. It consists of a commercially available back-illuminated InGaAs pin photodiode mounted on a ceramic block with an active diameter of 25μm and a typical responsivity of 0.8 A/W at 1300nm, and followed by three stages of common-source HEMT amplifiers. The receiver is implemented in hybrid integrated circuit form on an alumina substrate with a relative dielectric constant of 9.9. The photodiode is modelled by measuring the s-parameters. A capacitance of 0.1pf and a series resistance of 16Ω were obtained from the circuit model. The parasitic inducances and capacitances are absorbed by an appropriately designed noise matching network. To obtain a wide dynamic range, the first stage amplifier is designed as a transimpedance type with a feedback resistance of 900Ω. The first stage FET is a PHEMT chip with a gate length of 0.25μm and a gate width of 0.34μm at 4GHz. The PHEMT is biased at $V_{dd} = 2V$ and $I_{ds} = 10mA$ for the minimum noise figure.

The noise matching network is designed using a first-order network to simplify the design. In the design, the inductance is implemented using a microstrip line and a bonding wire. The microstrip line is introduced to control the Q factor of the matching network, which makes it possible to design the receiver circuit to have a flat gain response. Low noise performance is attainable because the noise matching network is implemented using lossless reactive components, and tunes out the circuit noise of the first stage feedback amplifier. The noise matching network is based on the noise figure concept as explained in [4]. The noise performance and electrical performance are simultaneously optimised using a commercial microwave simulation tool. The second stage and the third stage amplifiers are used for additional gain and output matching, respectively.

**Measurements**: The frequency responses of the transimpedance and equivalent input noise current are shown in Figs. 2 and 3, respectively. In these Figures, the optical receiver is designed to have an average transimpedance gain of 62.5dB, to reduce the noise contribution from the following amplifier stages, and an equivalent input noise current of < 7pA/Hz over the bandwidth. The measured transimpedance in Fig. 2 shows that the transimpedance gain agrees well with the prediction but that the shape of the curve is a little different from the prediction. This is mainly caused by the fact that the circuit parameters used in the implementation are not the same as those used in the simulation. A 3dB
bandwidth of 7.2GHz with a transimpedance of 60.7 ± 1.5dB is obtained. The measured output return loss is less than -9.6dB over the bandwidth, which resulted in a good impedance matching with a following amplifier.

The measured and simulated equivalent input noise current curves in Fig. 3 agree well over the whole frequency range, which means that the noise prediction using the microwave noise parameters supplied by the data sheet of the HEMTs is accurate, and that the matching network is quite accurately implemented. The average equivalent input noise current over the frequency range is 6.73pA/√Hz, which predicts an ideal receiver sensitivity of -25.3dBm at a BER of 10⁻⁹.

The measured output return loss is less than -9.6dB over the bandwidth, which resulted in a good impedance matching over the bandwidth, which predicted an ideal receiver sensitivity of -25.3dBm at a BER of 10⁻⁹.

Conclusion: We report an optical receiver front-end which employs a noise-matching network and transimpedance amplifier using a commercially available pin photodiode and a pHEMT with a gate length of 0.25μm and a noise figure of 0.34dB at 4GHz. The experimental results show a sensitivity of -23.5dBm at 10Gbit/s and a dynamic range of 23.5dB. To our knowledge, the measured sensitivity and dynamic range are the best results reported at 10Gbit/s for a pin-based receiver to date.

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Fig. 2 Frequency response of transimpedance gain

- - - - measured
- - - - predicted

Fig. 3 Frequency response of equivalent input noise current

- - - - measured
- - - - predicted

To measure the sensitivity of the receiver, a 40dB amplifier is cascaded to boost up the receiver output signal level for a bit error rate test set. A measured sensitivity of -23.5dBm is obtained using a PRBS NRZ data pattern with a length of 2¹⁻¹, which is modulated by an LiNbO₃ Mach-Zehnder external modulator with an 11dB extinction ratio. To our knowledge, this is the best measured sensitivity reported for a 10Gbit/s pin-based receiver. Fig. 4 shows the BER curve for this measurement. It is believed that the sensitivity penalty of 1.8dB is mainly caused by the linear channel imperfections (frequency response and group delay) and finite extinction ratio of the optical transmitter.

The dynamic range of the receiver is also tested by varying the input optical power together with an optical amplifier and an optical attenuator. The maximum optical power which can be coupled into the fibre of the receiver is > 0dBm. The measured dynamic range is ≥ 23.5dB.

Fig. 4 BER curve for 10Gbit/s pin-HEMT optical receiver

optical power, dBm

bit error rate

References


AlAsSb/AlGaAsSb Bragg stacks for 1.55μm wavelength grown by molecular beam epitaxy

J.C. Harmand, F. Jeannès, G. Le Roux and M. Juheal

Indexing terms: Distributed Bragg reflector lasers, Molecular beam epitaxial growth