REGENERATION OF 1-GBIT/S SIGNALS AFTER TRANSMISSION OVER AN OPTICAL FIBER

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ABSTRACT

A circuit containing step-recovery diodes is used to regenerate signals in the 1-Gbit/s range: A PN sequence modulates a GaAlAs laser and is then transmitted over 0.91 km of graded-index fiber. The received signal, distorted mainly due to fiber dispersion, is fully restored to the original NRZ format.

Introduction

Step-recovery diodes (SRD's) are well suited as basic elements in pulse regenerator and multiplexer circuits at high bit rates. Preliminary diode regenerators were described previously.[1,2,3] Use is made in these circuits of the charge-storage capability and the fast switching behavior of SRD's. Here we describe an improved regenerator circuit and its application to the regeneration of PCM-type signals in the 1-Gbit/s range after their transmission over an graded-index fiber.

Regenerator Circuit

Fig. 1 shows the improved regenerator configuration which is of push-pull type and which was implemented as hybrid-integrated circuit. The regeneration process consists principally of a charging phase and an immediately following discharging phase. During the charging interval the input pulse v_S to be regenerated disturbs the balance of the charge in the diffusion capacitances of the step-recovery diodes. (DC bias not shown). In Fig. 1 the polarity of the Schottky diode SD provided for isolation purposes is chosen in such a way that positive input pulses can be handled. The input current injects an additional charge into both SRD_1 and SRD_2' and removes the same amount from the basic charge in both SRD_1' and SRD_2. During the immediately following discharging phase as a result of the continuous signals of the two sinusoidal pump (clock) generators which are in antiphase, the remaining differential charges of the step-recovery diodes are removed. The diodes SRD_1' and SRD_2 switch off after having delivered their charges. As the symmetry is now lost, the pump voltage v_P produces a positive output pulse across the load R_L until SRD_1 is discharged, too. Simultaneously the SD blocks, which leads to a clear separation between the input and output paths. The leading edge of the output pulse is formed by SRD_1' and the trailing edge by SRD_1. Both the pump voltage amplitude and the differential charge determine the duration in which energy is transferred from the pump source to the load resistance. If no input is present, the circuit delivers no output signal owing to the then undisturbed symmetry during the complete operation cycle, a property the previous circuits[1,2,3] did not possess sufficiently.

Using commercially available SRD's, the regenerator can be operated in the range from about 0.25 to 1.5 Gbit/s. The regeneration consists of a voltage and power amplification and of a pulse re-shaping and retiming. At 1 Gbit/s a power gain of 8.5 dB and a voltage amplification of 13.5 dB were experimentally obtained from a single stage. Because of the circuit responding to the time integral of the injected current, possible time jitter of the input signal is removed. The regeneration process becomes particularly obvious if the input signal has experienced a broadening of the pulses, e.g. due to dispersion of the transmission path (cable, fiber) by which an RZ (return to zero) bit stream to be transmitted changes more or less to an NRZ pattern. Fig. 2 shows an (assumed) distorted signal of 1 Gbit/s,whereas Fig. 2b depicts the calculated corresponding output signal of the diode regenerator stage obtained by using a nonlinear network analysis program. The shown behavior agrees well with the experimental results (see Fig. 5).

The push-pull regenerator investigated here requires input signals with amplitudes of at least a few hundred mV. Amplitudes down to 10 - 20 mV can be handled by an SRD regenerator of different design which employs a hybrid-T structure and which was described elsewhere.[2,3,4]

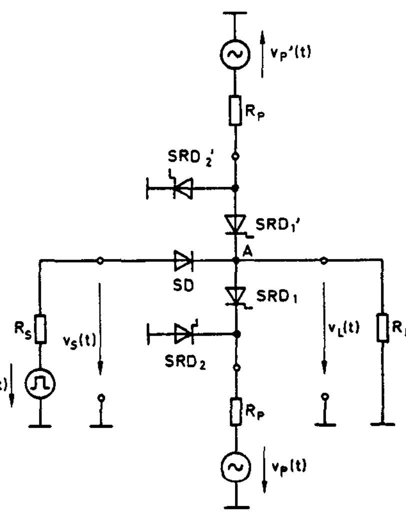

Fig.1 Push-pull regenerator circuit

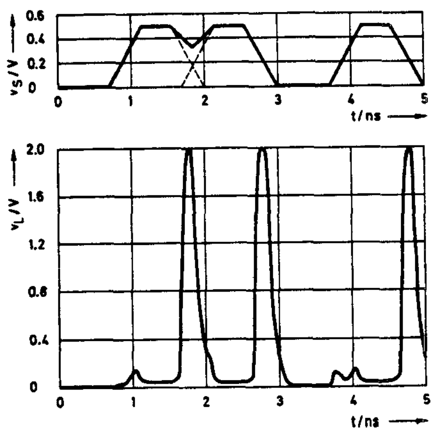

Fig.2 (a) Assumed regenerator input signal, (b) calculated corresponding output signal

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Optical Transmission Set-up

To prove the calculated regeneration properties of the push-pull circuit, fiber-optic transmission experiments were carried out. Particularly, the set-up shown in Fig. 3 was used: A GaAlAs DHS laser was modulated by a 0.95 Gbit/s PN (pseudo-noise) generator of transmission-line feedback type[5] which delivered repeated

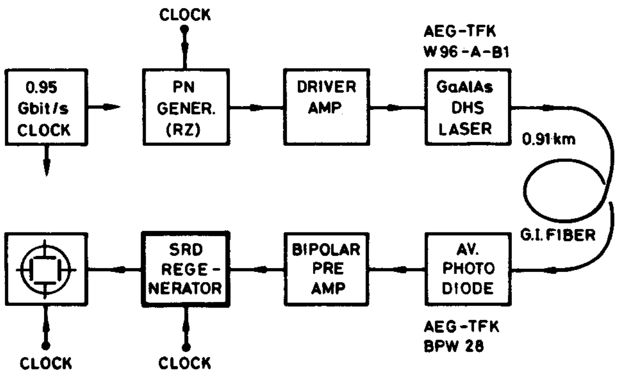


Fig.3 Set-up of transmission experiment

63-bit sequences. The light pulses at λ = 830 nm were then transmitted over a graded-index fiber of 0.91 km length and detected by an Si avalanche photodiode. Following a preamplification in a bipolar-transistor circuit with an upper frequency limit of 1.5 GHz, the received bit stream was regenerated by the circuit of Fig. 1 (SRD's: Aertech A4S 386). The experiment was not aimed at achieving a transmission path as long as possible. Rather, by using a graded-index fiber of the type employed, the degree of pulse broadening desired for this experiment was obtained already after about 1 km. Fig. 4 indicates how a typical single pulse of 200 ps halfwidth was received at the end of the fiber of 0.91 km length; no significant changes were obtained by using different diode-laser types.

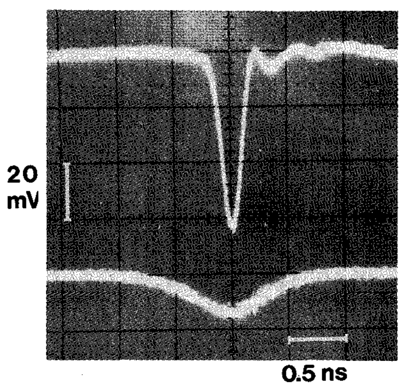
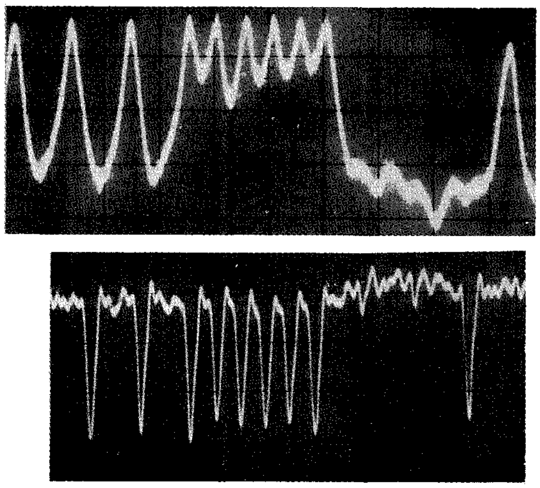


Fig.4 Single pulse before (top) and after (bottom) transmission over 0.91 km of g.-i. fiber

The clock signal required for operating the diode regenerator was in the present experiment not extracted from the received signal but taken directly from the basic clock generator that was used to produce the PN signal at the transmitting end. The derivation of the clock at the receiving end, by employing appropriately modified standard methods like PLL techniques, should not present principal difficulties, cf.[6].

Regeneration Results

As a main result of the present experiments, Fig. 5a shows the detected 0.95 Gbit/s signal as it was obtained behind the transistor pre-amplifier. Due to the frequency spectrum of the laser diode and mainly because of the fiber dispersion, the pulses of the PN signal are considerably broadened, overlapping in the sequence of "1" bits so that there almost an NRZ bit pattern is obtained. The same part of the signal, but now regenerated by the diode circuit, is shown in Fig. 5b. It is seen that the RZ format is clearly restored, as necessary for instance when a following diode laser has to be modulated. Since the high-frequency components of the original modulation pulses (before transmission over the fiber) are restored in the diode circuit, the requirements on the bandwidth of the preamplifier can be reduced. Therefore, this amplifier can rather be optimized with regard to both a maximum amplification and an advantageous signal-to-noise ratio.



(a) vert.: 10 mV/div. horiz.: 2 ns/div.

(b) vert.: 0.2 V/div. horiz.: 2 ns/div.

Fig.5 (a) Part of received PN sequence after preamplification, (b) corresponding signal after regeneration by the diode circuit.

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